State of California
The Resources Agency
Department of Water Resources

DRAFT FINAL REPORT ON THE EVALUATION OF PROJECT EFFECTS ON NON-FISH AQUATIC RESOURCES (SP-F1, TASKS 1 & 2)

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

Introduction: Aquatic macroinvertebrate and plankton communities are important components of the biological food web in Project waters. They are an important food source for fish species found within the Oroville Facilities and their community structure can provide general information on ecosystem health. The distribution and community structure of non-fish aquatic resources in Project waters is determined by four broad categories of factors: (1) physiological constraints, (2) trophic factors, (3) physical constraints, and (4) biotic interactions.

Purpose: The purpose of this study was twofold. The first purpose was to document the status of existing aquatic macroinvertebrate and plankton communities based on field study results, and provide a description of potential environmental effects on these resources based on a review of the existing literature (Task 1). The second purpose was site-specific and sought to evaluate the current and potential future operational effects of the Oroville Facilities on aquatic macroinvertebrates, phytoplankton, and zooplankton residing in the Project reservoirs and river habitats within the Study area (Task 2).

Results and Products: A review of field study results and existing literature was conducted to meet requirements for Task 1. The information from Task 1 was then used to evaluate the current and potential future operational effects of the Oroville Facilities (Task 2). Key results from macroinvertebrate, phytoplankton, and zooplankton data collection (Task 1) are presented below.

Aquatic Macroinvertebrates:

- Immature life stages (larvae or nymphs) of true flies, mayflies, and caddisflies were the most prevalent organisms sampled from all sites combined.
- Collectors, filterers, and grazers were the most dominant functional feeding groups in the Study area from all sites combined.
- Generally, highest taxa richness occurred in tributaries to Lake Oroville, while lowest taxa richness occurred at the collection site in the Lake Oroville inundation zone, the Feather River site upstream of the Feather River Fish Hatchery, and at several Feather River sites between the Thermalito Afterbay Outlet and Honcut Creek.
- The number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa varied widely across all sites (4 to 29); the highest number of EPT taxa occurred in the area upstream of the Lake Oroville inundation zone and the lowest was observed in the Lake Oroville inundation zone.
- Generally, macroinvertebrate diversity was consistent with expectations for large rivers in the Sacramento-San Joaquin watershed.
- In a concurrent DWR/CSU-Chico collaborative study, overall invertebrate densities in the Feather River below the dam varied substantially between

seasons but dominant taxa were similar to those of the Feather River sites in the DWR study.
- The benthic macroinvertebrate community downstream of the Fish Barrier Dam and in areas upstream of Lake Oroville had high percentages of filterers, suggesting that plankton (i.e., food for fish) is not limiting both upstream and downstream of Oroville Dam.
- The macroinvertebrate community at all the field stations included taxa that are important prey of the fish species in the river.

Phytoplankton and Zooplankton:
- Phytoplankton from nine taxonomic groups were identified from 14 collection sites.
- Overall, phytoplankton communities were dominated by diatoms (57%), green algae (16%), Cryptomonads (9%), and blue-green algae (9%). Five other taxonomic groups accounted for the remaining nine percent.
- Diatoms were the most abundant algae type in Lake Oroville, Thermalito Complex, and the Fish Barrier Pool, while green algae were dominant in the Oroville Wildlife Area.
- Zooplankton from three taxonomic groups were identified from six collection sites.
- Rotifers were the most prevalent group at all Lake Oroville stations, followed by Copepoda and Cladocera.
- The Thermalito Afterbay was dominated by copepods, followed by cladocerans and rotifers.

Potential Current Project Effects on Non-Fish Aquatic Resources:
Field data and information from technical studies related to the Oroville Project provided information on current environmental conditions that was used to evaluate the current Project effects on macroinvertebrates. Project impacts were evaluated using a "directional assessment", based on a five-point rating system (strongly negative, negative, neutral, positive, and strongly positive). Current Project operations that have resulted in areas of armored substrates and altered temperature regimes in the Feather River between the Fish Barrier Dam and Thermalito Afterbay Outlet were considered "negative" impacts to macroinvertebrates. Fish stocking also was considered a negative impact to macroinvertebrates in the Feather River below the dam. These three current project actions are believed to have contributed to the less diverse macroinvertebrate community below the dam compared to the areas upstream of the Lake Oroville inundation zone, as noted in the list above. Note, however, that even before the Project existed, physical habitat upstream of the Lake Oroville inundation area was different than habitat below the current location of the Fish Barrier Dam. Thus, without historical data, estimating the influence of the Project on macroinvertebrate diversity in the Feather River is difficult. Current Project operations that provide minimum instream flows downstream of the Fish Barrier Dam are believed to benefit macroinvertebrates, as dampening of the natural hydrograph has limited

annual flushing flows and provided more favorable conditions for colonization and expansion.

A similar analysis methodology was used to evaluate current Project effects on plankton resources. Current Project impacts were evaluated using a “directional assessment”, based on a five-point rating system (strongly negative, negative, neutral, positive, and strongly positive). Project operations that increase water temperatures in the Thermalito Afterbay Outlet and Lake Oroville are likely to increase plankton production in these waters. Habitat enhancement activities for fish species in Lake Oroville were assigned a "negative" rating for plankton resources because many fish species use plankton as a food source during some life stages. Therefore, based on current activities to improve habitat for these species, it was thought that increased predation on plankton has occurred.

Potential Future Project Effects on Non-Fish Aquatic Resources:
Data from related technical studies provided information on projected environmental conditions that was used to evaluate the potential Project effects on non-fish aquatic resources. Descriptions of Resource Actions currently being considered by the Environmental Work Group also were used for impact analysis. Since the Resource Actions that will be included in the Proposed Project were not finalized at the time of this report and since many contained only a coarse level of detail, the assessments of Project impacts on macroinvertebrate and plankton communities should be considered preliminary, and subject to change as Resource Actions or proposed changes to Project operations are further refined and implemented. Project impacts were evaluated using a “directional assessment”, based on a five-point rating system (strongly negative, negative, neutral, positive, and strongly positive).

With regard to aquatic macroinvertebrates, a rating of neutral or positive was assigned to all but one category of Resource Actions that were considered for this report. Gravel replenishment and side channel restoration in the Feather River below the dam were considered to have strongly positive effects. Potential actions to lower water temperature in the Feather River and proposed increased flow below the Dam were considered positive for macroinvertebrate communities. A neutral rating was assigned to potential effects of ramping, as no net changes from baseline conditions would be expected. A negative rating was assigned to fish stocking based on the fact that fish are major consumers of macroinvertebrates.

With regard to plankton, ratings assigned to the categories of Resource Actions considered for this report ranged from negative to strongly positive. Side channel restoration in the Feather River below the dam was considered to have a strongly positive effect on plankton. Potential actions to lower water temperature in the Feather River, increase water level in the Thermalito Afterbay, and transport adult salmonids to Lake Oroville tributaries were considered to have positive effects on plankton communities. A negative rating was assigned to Resource Actions in the Oroville

Wildlife Area designed to eliminate undesired plant species. This rating also was assigned to fish stocking activities in Project waters downstream of Oroville Dam.

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1.0 INTRODUCTION

California Department of Water Resources (DWR) initiated the relicensing process for their Oroville Hydroelectric Project (Project) in 2001, FERC #2100. Based on stakeholder feedback derived through the collaborative process, concern was expressed that the current or future mode of operation of Oroville facilities could affect aquatic non-fish resources. In the early stages of this process, DWR identified several priority issues, one of which is Project effects on non-fish aquatic resources. Thus, this study was conducted to evaluate Project effects on non-fish aquatic resources and respond to issues, concerns, and comments regarding the macroinvertebrate and plankton resources found in Project waters.

Aquatic macroinvertebrate and plankton communities are important components of the biological food web in the various impoundments within the Project area as well as the tributaries upstream from Lake Oroville and the Feather River downstream from Oroville Dam. Understanding the composition and structure of phytoplankton, zooplankton, and aquatic macroinvertebrate communities is important for understanding effects across trophic scales and for evaluating other primary licensing issues, such as the status of resident and anadromous fishes in the Feather River basin. This study, as well as other resource studies, is important for developing adequate existing information from which Project effects on resources can be determined and for developing appropriate protection, mitigation, and enhancement measures as the licensing process moves forward.

Phytoplankton, zooplankton, and aquatic macroinvertebrates are important components of the food web for anadromous and resident fish, as well as amphibians, birds, mammals, and other invertebrates. The construction of Oroville Dam inundated approximately 15,810 acres (maximum operating level) and changed the hydrologic cycle of the Feather River and its nearby tributaries. These changes affected invertebrate and plankton life cycles and communities that have evolved over time. Fluctuating reservoir levels, controlled flows downstream of the Project, sediment accumulation, and less-frequent scouring events have caused changes to the aquatic habitat within the Project area and likely have affected non-fish aquatic resources. The effects of Oroville Dam on non-fish aquatic resources are consistent with environmental impacts associated with hydropower projects across the world (World Commission on Dams 2000).

1.1 BACKGROUND INFORMATION

1.1.1 Statutory/Regulatory Requirements

Section 4.51(f)(3) of Volume 18, Code of Federal Regulations (CFR) requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower Projects, including a discussion of fish, wildlife, and botanical resources in the vicinity of the Project. The discussion needs to identify the potential effects of the Project on these resources, including a description of any anticipated continuing effect for on-going and future operations. This study fulfills some of these requirements, by evaluating the potential effects on aquatic macroinvertebrate and plankton communities within the Project boundary.

1.1.2 Study Area

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided in Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir.

With the exception of a section of the Feather River in the low flow channel between the Feather River Fish Hatchery and about a mile upstream of the Thermalito Afterbay Outlet (approximately River Mile (RM 60), the study area is located entirely within the FERC Project boundary. Twelve distinct habitat areas were defined within the study area to assess the potential Project effects on non-fish aquatic resources. The following twelve habitats were delineated on the basis of the aquatic conditions including water velocities, water temperatures, substrate composition, and surface fluctuation differences:

1. Area Upstream of Lake Oroville Inundation Zone
2. Lake Oroville Inundation Zone (i.e., habitat exposed as reservoir level drops seasonally)
3. Lake Oroville Reservoir
4. Thermalito Diversion Pool
5. Thermalito Forebay
6. Thermalito Afterbay
7. Power Plant/Fish Barrier Pool
8. Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet
9. Lower Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek
10. Oroville Wildlife Area
11. Lower Feather River downstream of Honcut Creek

and

12. Sacramento and Yuba Rivers

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cubic feet per second (cfs) and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cfs of water into the river.

The Power Canal is a 10,000-ft-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-ft-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay Outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000 acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

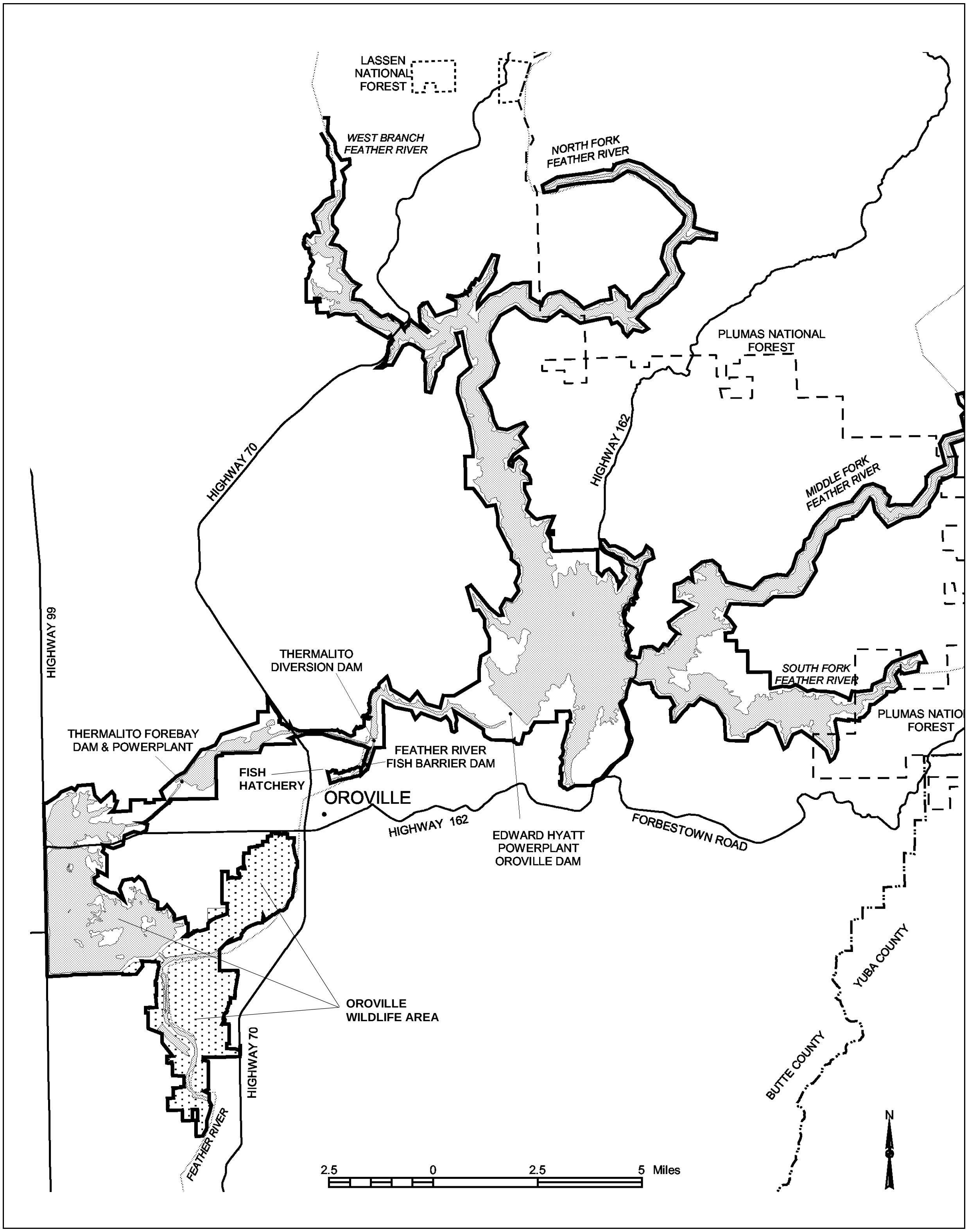

Figure 1.2-1 Oroville Facilities FERC Project Boundary.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for Project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, “Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife,” sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52 ºF for September, 51 ºF for October and November, 55 ºF for December through March, 51 ºF for April through May 15, 55 ºF for last half of May, 56 ºF for June 1-15, 60 ºF for June 16 through August 15, and 58 ºF for August 16-31. A temperature range of plus or minus 4 ºF is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

National Oceanic and Atmospheric Administration (NOAA) Fisheries (formerly National Marine Fisheries Service) has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and State Water Project (SWP) on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65 ºF on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California Independent System Operator anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65 ºF from approximately April through mid May, and 59 ºF during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 af (July 2002) are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it flows into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

The purpose of this study was to obtain and review existing information on macroinvertebrates and plankton to qualitatively evaluate the Project's effects on non-fish resources. This information is useful for evaluating direct, indirect, and cumulative effects of the Oroville Facilities required to comply with the FERC environmental review process under the U.S. Environmental Protection Agency (USEPA) and Endangered Species Act (ESA) consultation information requirements. This study was initiated to collect and compile baseline information on aquatic macroinvertebrate and plankton communities in waters influenced by Project operations in order to evaluate potential Project effects and to provide a foundation for development of future PM&E measures, if needed. The health of aquatic macroinvertebrate and plankton communities is related to a variety of environmental factors in the Project area. Of significance to biotic communities are potential impacts to water temperature, discharge in the Feather River below Oroville Dam, reservoir fluctuations, and changes to the hydraulic nature of the system that potentially could affect water quality.

3.0 STUDY OBJECTIVE(S)

The overall goals of this study were to describe the aquatic macroinvertebrate and plankton resources located within the Project boundary and to evaluate the potential impacts to these resources that result from ongoing and future Project operations. The study focused specifically on macroinvertebrates and plankton as they are indicators of overall water quality and serve as a prey base for fish. Specific study objectives are listed below.

Objective 1. Describe the aquatic macroinvertebrate, phytoplankton, and zooplankton communities found within Project waters including information on community structure and their habitat conditions.

A review of existing literature, field studies, and Project data was conducted to meet the first objective. The review presented information on operations or environmental conditions that affect plankton and aquatic macroinvertebrate communities within Project waters, as well as information on how aquatic macroinvertebrates and plankton communities have responded to environmental change in other river systems. The review culminated in a description of the current condition of aquatic macroinvertebrate and plankton communities present in both the impounded and free-flowing freshwater habitats within the facility boundaries.

Objective 2. Qualitatively evaluate effects on the aquatic macroinvertebrate and plankton communities that may result from current operations or operational changes at the Oroville facilities.

The lack of long-term field data from Project waters on the abundance and composition of macroinvertebrate and plankton communities prevented the pursuit of a quantitative or “modeling-based” assessment of Project operations on non-fish resources within the Project boundary. Instead, a five-point categorical scale (strongly positive, positive, neutral, negative, strongly negative) was used to provide a general assessment of the likelihood of a positive or negative effect from operation of the Oroville facilities. The general effects of physical and chemical alterations from future Project operations on plankton and macroinvertebrate communities were based on a review of the life history requirements for plankton and macroinvertebrates, field data, Resource Actions currently being examined by the Environmental Work Group, and scientific judgment.

4.0 METHODOLOGY

4.1 STUDY DESIGN

Two recent field studies conducted in Project waters provided data on macroinvertebrate and plankton communities. In the first study, macroinvertebrate samples from 21 riffle sites and six underwater (i.e. ponar) sites were collected by DWR and analyzed to determine the number of taxa and calculate measures of community composition. Phytoplankton from 14 stations and zooplankton from six stations also were collected by DWR to determine number of taxa and calculate measures of community composition. The second study was conducted by California State University, Chico (hereafter referred to as CSU-Chico) and focused on collecting benthic and drifting macroinvertebrates in the Feather River. Samples were collected from eight sites between the Fish Barrier Dam and Thermalito Afterbay Outlet and four sites between the Thermalito Afterbay Outlet and Honcut Creek.

For all DWR macroinvertebrate collections, the DFG modification (i.e., California Stream Bioassessment Procedure; DFG 1999) of the USEPA rapid bioassessment method (USEPA 1989, Barbour *et al.* 1999) was used to sample aquatic macroinvertebrate communities at stream sites within the Project area. In the fall, when stream discharge was lower, target areas were sampled at three locations within each transect with a kick screen and metal frame using the DFG rapid bioassessment protocols. Three individual samples were collected across each transect and combined, resulting in a combined sample at each transect. The metal frame had a 3 ft^2 sampling area, thus with three sites within a transect the total area sampled was 9 ft^2. During spring, or when water depth precluded effective use of the kick screen and metal frame, benthic macroinvertebrates were sampled with a ponar sampler. Sites in the Oroville Wildlife Area and downstream of the Project Boundary were sampled with a ponar sampler. The ponar sampler had a sampling aperture of 0.56 ft^2 (9 by 9 inches).

At sites within the Lake Oroville inundation zone, riffle areas in the major tributaries to Lake Oroville were sampled for macroinvertebrates in fall 2002 and spring 2003 to determine the status of benthic macroinvertebrates and evaluate seasonal changes in abundance and community structure. Macroinvertebrate sampling in the fall was conducted with a kick screen and a ponar grab was used in the spring. Spring sampling was conducted to assess whether habitat exposed by reservoir drawdown in the fall was eliminated in the spring due to flooding as the reservoir refills. Organisms collected from these sties were processed using procedures similar to samples collected from other sites in the Feather River and upstream tributaries.

In the study conducted by DWR/CSU-Chico, benthic and drifting macroinvertebrate data were collected at locations in the lower Feather River upstream and downstream of the Afterbay Outlet. Four locations between the Fish Barrier Dam and Thermalito Afterbay Outlet and four locations between the Thermalito Afterbay Outlet and Honcut Creek in the Feather River were sampled, in addition to four locations in side channels adjacent to the sites between the Fish Barrier Dam and Thermalito Afterbay Outlet. Overall, twelve sample sites were established, four in the main river channel of each section (Fish Barrier Dam to Thermalito Afterbay Outlet: river miles 66.6, 61.9, 61.0, 60.1 and Thermalito Afterbay Outlet to Honcut Creek: river miles 58.5, 55.5, 53.5, 47.2) and four in side channels adjacent to the sites in the reach between the Fish Barrier Dam and Thermalito Afterbay Outlet (Appendix A-3). All of the samples were collected from riffles. Each site was sampled in January, April, and July 2002.

Benthic invertebrate samples from the DWR/CSU-Chico study were collected with a modified Surber sampler using an adaptation of the DFG's protocol for rapid bioassessment (DFG 1999). The modified Surber sampler was 1.0 meter tall by 0.5 meter wide with a 360 um mesh. An area of .09 m^2 was cleaned in front of the net during sampling. This cleaned area was described as the sampling grid. At each site, three samples were collected (one in the middle and one near each bank) along three randomly chosen transects running perpendicular to the flow. The three samples were collated from each transect into one composite sample and preserved in 90 percent ethanol. The substrate was disturbed within the sampling grid for ten minutes to standardize collections.

For each transect, the catch was subsampled according to the adaptation of the DFG's rapid bioassessment procedures (DFG 1999). In the lab, each sample was drained of ethanol using a number 30 sieve and the material was laid out in a thin, homogeneous layer on a metal tray divided into 54 grids (4 x 4 centimeter). All invertebrates were removed with the aid of a dissecting microscope from randomly selected grids until at least 500 individuals were found. Samples from each transect were sorted and identified separately and then averaged together to calculate a site mean.

Several metrics were used to characterize the macroinvertebrate community, including the Shannon Diversity Index (SDI), functional feeding groups, tolerant/intolerant taxa, cumulative taxa (i.e., species richness), EPT taxa, and two EPT indices. The Shannon Diversity Index is logarithmic, usually ranges from 1.5 to 3.5, and reaches its maximum value when all species are distributed evenly (El Dorado Irrigation District 2002). The index was calculated in this study with "non-distinct" taxa included and data was presented in base e logarithms. Specimens identified only to the Family level were included in our SDI calculations. The cumulative taxa observed at each sampling site was reported as species richness for this study. The tolerance index used in this study was calculated by dividing the tolerance value of an individual species by the abundance of the entire sample, multiplying by the abundance of the individual species, then summing the results for all species present. The EPT Index was calculated using the total number of EPT species (including non-distinct taxa) divided by the number of total organisms. The sensitive EPT was index was calculated in a similar manner, except that only EPT taxa (including non-distinct taxa) with tolerance values less than four were used. The expected response to impairment for macroinvertebrates for each metric is provided in Table 4.1-1.

Table 4.1-1 Metrics used to Describe Benthic Macroinvertebrate Samples Collected following the California Stream Bioassessment Procedure.

Metric	Description	Expected Response to Impairment
Richness Measures		
Cumulative Taxa	Total number of individual organisms	decrease
EPT Taxa	Number of taxa in the Ephemeroptera, Plectoptera, and Trichoptera insect orders	decrease
Ephemeroptera Taxa	Number of mayfly taxa (genera)	decrease
Plectoptera Taxa	Number of stonefly taxa (genera)	decrease
Trichoptera Taxa	Number of caddisfly taxa (genera)	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly, and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly, and caddisfly larevae with Tolerance Values of 0 through 3	decrease
Shannon Diversity Index	General measures of sample diversity that incorporates richness and evenness	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighed for abundance of individuals designated as pollution tolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1, or 2	increase
Percent Tolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 8,9, or 10	increase
Percent Hydropsychidae	Percent of organisms in the caddisfly family Hydropsychidae	increase
Percent Baetidae	Percent of organisms in the mayfly family Baetidae	increase
Percent Chironomidae	Percent of organisms in the truefly family Diptera	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Functional Feeding Groups		
Percent collectors	Percent composition of taxa that collect or gather fine particulate organic matter	increase
Percent filterers	Percent composition of taxa that filter fine particulate organic matter	increase
Percent scrapers	Percent composition of taxa that graze upon periphyton	variable
Percent predators	Percent composition of taxa that feed on other organisms	variable
Percent shredders	Percent composition of taxa that shreds coarse particulate matter	decrease

Phytoplankton were sampled from impounded Project waters and the lower Feather River. Five sites were located in the arms and main body of Lake Oroville, six sites were located in the Thermalito Complex, and three sites were located in ponds within the Project boundary (Appendix B).

Phytoplankton were sampled monthly with a plankton net towed from 30 feet in depth to the surface in Lake Oroville and from the bottom in the other impounded areas. Phytoplankton were identified and enumerated.

Zooplankton were collected from six stations in Lake Oroville and the Thermalito Afterbay during 2002 and 2003 (Appendix C). Sampling methodology for zooplankton was similar to that described for phytoplankton. Zooplankton were identified, enumerated, and measured volumetrically. Results from phytoplankton and zooplankton sampling were obtained electronically from the Interagency Ecology Program (IEP) data vaults (IEP 2003).

4.2 EVALUATION OF CURRENT PROJECT EFFECTS

An evaluation of current project effects on aquatic macroinvertebrate and plankton communities was conducted using a directional analysis. The analysis, which was based on a general assessment of likely Project effects, used a five-point scale [strongly positive, positive, neutral, negative, strongly negative]. Descriptions of current Project operation and professional judgment were used to assess impacts to macroinvertebrate and plankton communities in Project waters. Information to support the directional assessment also was obtained from two field sampling studies, information previously presented as part of Task 1, and other related study plans associated with the Oroville Project.

Two matrices summarizing the effects to macroinvertebrates and plankton from current project operations were used to evaluate environmental impacts to these resources. The matrices identified key impacts and the applicable geographic areas related to potential impacts. The matrices contained a brief description of current operations (baseline conditions), a general impact description, and a directional rating associated with the impact.

4.3 EVALUATION OF POTENTIAL FUTURE PROJECT EFFECTS

A description of the methodology used in the assessment of future Project effects is located in Section 4.2, Evaluation of Current Project Effects. A more precise analysis was not feasible because future Project operations were not clearly defined at the time this report was prepared. In lieu of clearly defined descriptions of the Project alternatives, professional judgment was used to identify potential future Project actions currently being examined by the Environmental Work Group (as of March 22, 2004) that could result in changes to environmental conditions (and thus changes to macroinvertebrate and plankton communities) in Project waters. Information to support the directional assessment also was obtained from two field sampling studies, information previously presented as part of Task 1, and other related study plans.

5.0 STUDY RESULTS

5.1 MACROINVERTEBRATES

Macroinvertebrate data collected by DWR were available from 27 sites (Appendix A-1). Summary data from these sites are presented in Appendix A-2. Summary data from 12 sites in the Feather River collected by the DWR/CSU-Chico collaborative study are presented in Appendix A-3.

5.1.1 Entire Study Area

Appendix A-2 provides summary information and the biological metrics that were used to support impact assessment for each of the 27 stations. Midge (Diptera:Chironomidae) and blackfly (Diptera:Simuliidae) larvae, baetid mayfly nymphs (Ephemeroptera: Baetidae), and hydropsychid caddisfly larvae (Trichoptera:Hydropsychidae) were present at all stations.

The macroinvertebrate community of all the stations included many taxa that are important prey of the fish species in the river. These taxa include all the true flies (Diptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). The stoneflies (Plecoptera), which were found in only 5 stations, are important prey of trout.

The number of cumulative taxa ranged widely from 16 to 49, with the highest taxa richness located in tributaries to Lake Oroville upstream of Oroville Dam (Appendix A-2). The number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa also varied widely across all sites (4 to 29 percent) (Table 5.1-1).

Shannon Diversity Index (SDI) values ranged from 0.9 to 2.6 throughout the Study area (Table 5.1-1). Diversity was lowest at the site upstream of the Yuba River confluence with the Feather River and highest upstream of Lake Oroville in the Middle Fork and West Branch of the Feather River and in the Fall River (Appendix A-2). Except for the site upstream of the Yuba River confluence, diversity was relatively uniform downstream of Oroville Dam (Table 5.1-1). Macroinvertebrate diversity within the Project Boundary generally was consistent with expected values for large rivers in the Sacramento-San Joaquin watershed (CMARP 1998).

Collectors, filterers, and grazers generally were the most dominant functional feeding groups in the Study area. Collectors exceeded 25 percent of the total sample at all sites and usually were the most abundant functional feeding group. Predators and shredders were least prevalent at sites across the Study area (Appendix A-2).

Table 5.1-1a. Summary information by geographic area for macroinvertebrates collected by DWR and CSU-Chico with a kick screen and metal frame in fall 2002 and spring 2003.

	Entire Study Area	Stream Reaches Upstream of Lake Oroville Inundation Zone	Lake Oroville Inundation Zone	Feather River between Fish Barrier Dam and Thermalito Afterbay Outlet	Feather River between Fish Barrier Dam and Thermalito Afterbay Outlet[1]	Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek	Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek[1]	Oroville Wildlife Area	Lower Feather River downstream of Honcut Creek
Number of Sites	33	7	1	6	8	3	4	1	3
Cumulative Taxa	16-49	31-49	19	20-32	20-35	16-24	18-28	28	22-24
EPT Taxa	4-29	12-29	4	7-11	6-14	7-13	8-13	10	10-15
EPT Index (%)	5-95	10-68	47	5-69	11-81	67-84	46-95	72	68-84
Shannon Diversity Index	0.9-2.7	2.0-2.7	1.8	0.9-2.4	1.5-2.2	1.6-2.0	1.7-2.1	2.3	1.6-2.1
Tolerance Value	3.0-6.0	3.9-5.7	4.6	4.7-6.0	3.1-4.8	4.4-4.7	3.0-4.4	4.6	4.5-4.7
%Hydropsychidae	0-48	0-21	38	1-25	0-35	45-48	10-41	19	3-26
% Baetidae	3-57	3-27	7	1-42	7-55	14-31	11-47	30	42-57
% Chironomidae	3-83	9-54	30	10-83	3-54	8-18	3-48	14	8-24
% Collector	26-95	37-68	42	35-90	53-95	33-42	26-86	57	60-88
% Filterer	0-73	1-36	43	6-40	0-46	46-51	13-73	21	4-30
% Grazer	0-46	9-44	2	0-46	0-35	6-17	0-3	19	6-8
% Predator	0-12	0-12	12	3-10	0-2	1-2	not found	5	1-5
% Shredder	0-6	0-6	not found	none found	0-2	not found	0-4	not found	not found

Source: DWR sampling data 2002-2003
[1] Data obtained from CSU-Chico in 2003

Table 5.1-1b. Summary information by geographic area for macroinvertebrates collected by DWR with a ponar grab in fall 2002 and spring 2003.

	Entire Study Area	Feather River between Fish Barrier Dam and Thermalito Afterbay Outlet	Oroville Wildlife Area	Lower Feather River downstream of Honcut Creek	Sacramento and Yuba Rivers
Number of Sites	6	1	1	2	2
Cumulative Taxa	3-15	10	6	3	3-15
EPT Taxa	0-3	1	1	0-1	0-3
EPT Index (%)	0-30	1	2	0-2	0-30
Shannon Diversity Index	0.5-1.8	1.3	1.0	0.5-0.8	0.7-1.8
Tolerance Value	5.8-6.4	6.4	5.8	5.9-6.0	5.8-5.9
%Hydropsychidae	0-1	1	not found	not found	not found
% Baetidae	not found	not found	not found	not found	not found
% Chironomidae	1-79	1	61	13-37	19-79
% Collector	15-94	78	94	15-37	75-86
% Filterer	0-85	17	not found	58-85	0-14
% Grazer	0-5	not found	not found	0-5	0-1
% Predator	0-24	5	6	not found	0-24
% Shredder	not found	not found	not found	not found	not found

Source: DWR sampling data 2002-2003

5.1.2 Area Upstream of Lake Oroville Inundation Zone

Appendix A-2 provides summary information and biological metrics that were used to support impact assessment at each of the seven stations above Lake Oroville. Midge (Diptera:Chironomidae) and blackfly (Diptera:Simuliidae) larvae, baetid mayfly nymphs (Ephemeroptera:Baetidae), and hydropsychid caddisfly larvae (Trichoptera:Hydropsychidae) were present at all seven stations. Beetles (Coleoptera:Elmidae) also were present at all sites and were highly abundant at the Fall River and Sucker Run Creek locations.

The macroinvertebrate community of all the stations above Lake Oroville included many taxa that are important prey of the fish species in the river. These taxa include all the true flies (Diptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). The stoneflies (Plecoptera), which were found in only five of seven stations above Lake Oroville, are important prey of trout.

The number of cumulative taxa at each site ranged from 31 to 49, with the highest taxa richness located in the West Branch of the Feather River near Paradise. The lowest taxa richness was observed in Concow Creek, a tributary of the West Branch. The cumulative number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa varied widely across all sites above the dam (12 to 29 taxa). SDI values upstream of the reservoir were fairly uniform (excluding the one site in the Lake Oroville inundation zone), ranging between 2.0 and 2.7 among all sites above the reservoir. Macroinvertebrate diversity generally was higher compared to values at Feather River sites downstream of Oroville Dam, suggesting that upper sites have a more balanced invertebrate community. Note, however, that even before the Project existed, physical habitat upstream of the Lake Oroville inundation area was different than habitat below the current location of Oroville Dam.

In the North, Middle, and South Forks of the Feather River, collectors and filterers were the most dominant functional feeding groups. In the Fall River and Sucker Run Creek, grazers were dominant, suggesting that algal growth is high in these reaches. Predators and shredders were found infrequently (less than 18 percent combined) at all sites above Lake Oroville. Sampling sites in North and South Forks of the Feather River had the highest tolerance index values (i.e., most tolerant of impaired conditions) among all sites in the area above Lake Oroville. The site in the Fall River upstream of Feather Falls was the least impaired based on tolerance index values, and this site also contained the highest percentage of pollution intolerant taxa.

5.1.3 Lake Oroville Inundation Zone

The macroinvertebrate community at the site sampled in the Lake Oroville inundation zone was less diverse than the seven other sites in areas upstream of the lake, as measured by the number of cumulative taxa (19 taxa), Shannon Diversity Index (1.8), and cumulative number of EPT species (4 taxa) (Appendix A-2). Midges (Diptera:Chironomidae) and hydropsychid caddisfly larvae (Trichoptera:Hydropsychidae) were the most abundant taxa at this site. Similar to other upstream sites, the macroinvertebrate community in the inundation zone was dominated by collectors and filterers. Macroinvertebrates were not found in the Lake Oroville inundation zone during sampling in spring 2003 (pers. comm., J. Boles, DWR, 2004). Lack of macroinvertebrates during spring in the inundation zone was expected because habitat exposed by reservoir drawdown in the fall is eliminated in the spring due to flooding as the reservoir refills.

5.1.4 Feather River Between Fish Barrier Dam and the Thermalito Afterbay Outlet

DWR Collections--Riffle

Appendix A-2 provides summary information and biological metrics that were used to support impact assessment at each of the six stations in this reach. Midge (Diptera:Chironomidae) and blackfly (Diptera:Simuliidae) larvae, baetid mayfly nymphs (Ephemeroptera:Baetidae), and hydropsychid caddisfly larvae (Trichoptera:Hydropsychidae) were present at all six stations in moderate to high densities. Mayflies (Ephemeroptera:Leptohyphidae) , hydroptilid caddisfly larvae (Tricoptera:Hydroptilidae) , water mites (Trombidiformes:Sperchontidae), and aquatic worms (Oligochaeta) also were found at all DWR sampling sites in this reach in lower densities.

The macroinvertebrate community of all the DWR stations between the Fish Barrier Dam and the Thermalito Afterbay Outlet included many taxa that are important prey of the fish species in the river. These taxa include all the true flies (Diptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). Stoneflies (Plecoptera) were not present at these sites.

The number of cumulative taxa at each site within this reach ranged from 20 to 32, with the highest taxa richness located in Glen Creek. The lowest taxa richness was observed upstream of the Feather River Hatchery. The cumulative number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa was relatively uniform across all sites in this reach (8 to 11 taxa). The site upstream of the Feather River Fish Hatchery had the lowest percentage of EPT species while five other sites had levels of EPT composition higher than 25 percent. SDI values in this reach varied widely, ranging between 0.9 to 2.4 among all DWR sampling sites between the Fish Barrier Dam and the Afterbay Outlet. Two of three sites with the lowest diversity and highest tolerance values were located near the Feather River Fish Hatchery. The third Feather River site with metrics values indicating greater impairment than other stations in this reach was that located near Highway 162. The high impairment scores for stations near the Feather River Fish Hatchery may be related to its proximity to the Fish Barrier Dam.

Collector and filterer functional feeding groups were dominant at all sites except Glen Creek in this geographic area of the Feather River. These functional groups are expected in the greatest abundance below the dam due to the high amount of fine particulate organic matter available from upstream processing and dead plankton settling to the lower depths of Lake Oroville. Grazers and predators were less abundant than feeding groups such as collectors and filterers at the lower Feather River sites . At all lower Feather River sites except Glen Creek, predators accounted for less than 6 percent of the macroinvertebrates and grazers accounted for less than 8 percent. In Glen Creek, grazers dominated the sample (47 percent), followed in abundance by collectors (35 percent), and predators (10 percent). Shredders were not found at sites in the Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet.

CSU-Chico Collections--Riffle
Additional downstream populations of benthic macroinvertebrates were sampled at eight sites in the Feather River by CSU-Chico from river mile 47.2 to 66.6 in winter, spring, and summer 2002 (Appendix A-3). The dominant taxa at CSU-Chico sites were similar to DWR Feather River sites between the Fish Barrier Dam and Thermalito Afterbay Outlet. Aquatic macroinvertebrates in this reach of the Feather River were dominated by midges (Diptera:Chironomidae), baetid mayfly nymphs (Ephemeroptera:Baetidae), hydropsychid caddisfly larvae (Trichoptera:Hydropsychidae), mites (Oribatidae:Oribatid), and black flies (Diptera:Simuliidae). Data from the CSU-Chico study indicate that macroinvertebrate densities varied substantially between seasons, and dominant genera were similar to other sites in the reach of the Feather River between the Fish Barrier Dam and Thermalito Afterbay Outlet.

The number of cumulative taxa at each site within this reach ranged from 15 to 35, with the highest taxa richness located at the Eye Main site. The lowest taxa richness was observed upstream at the Robinson Main site. The cumulative number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa varied widely across all sites in this reach (6 to 14 taxa). SDI values in this reach were fairly uniform and consistent with all but one DWR sampling site in this reach (site upstream of the Feather River Fish Hatchery), ranging between 1.6 and 2.2 among all sites between the Fish Barrier Dam and the Thermalito Afterbay Outlet. Winter and spring collections generally had lower diversity compared to summer in this reach of the Feather River. Tolerance indices were relatively similar across stations and seasons at individual sites. Highly pollution-tolerant macroinvertebrates (i.e., those with tolerance values >7) were not observed at sampling stations in this reach. As with DWR riffle sampling, collectors and filterers were most abundant functional feeding groups during all seasons and at all sites.

DWR Collections--Submerged (Ponar)
Submerged sampling using a ponar grab at one site near the Fish Barrier Dam showed a less diverse macroinvertebrate assemblage than sampling with a kick screen and

metal frame in shallower sites within this reach. Ten cumulative taxa were collected during submerged sampling near the Fish Barrier Dam. One individual of one EPT species, *Oxyethria sp*., (Trichoptera :Hydropsychidae), was collected during sampling. The sample was dominated by aquatic worms (Oligachaeta) and freshwater crustaceans (Ostracoda).

5.1.5 Lower Feather River Downstream from Thermalito Afterbay Outlet to Honcut Creek

DWR Collections--Riffle

Appendix A-2 provides summary information and biological metrics that were used to support impact assessment at each of the three stations between the Thermalito Afterbay Outlet to Honcut Creek. Midges (Dipteran:Chironomidae), baetid mayfly nymphs (Ephemeroptera:Baetidae), and moths (Lepidoptera:Pyralidae) were present at all three stations in moderate to high densities.

The macroinvertebrate community of all the stations in this reach included many taxa that are important prey of the fish species in the river. These taxa include all the true flies (Diptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). Stoneflies (Plecoptera) were not found in this reach.

The number of cumulative taxa at each site ranged from 16 to 26, with the highest taxa richness located at the two sites immediately below the Thermalito Afterbay Outlet. The lowest taxa richness was observed above Honcut Creek, which is located at the downstream end of the reach. The cumulative number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa were relatively similar across all sites in this reach (7 to 13 taxa). SDI values in this reach were fairly uniform, ranging between 1.6 and 2.1 among all sites in the reach. Macroinvertebrate diversity and tolerance indices in this reach generally were similar to values at Feather River sites between the Fish Barrier Dam and Thermalito Afterbay Outlet.

Collectors and filterers were the most dominant functional feeding groups at all three sites. No shredders were found at these sites and predators were observed infrequently (<2 percent).

CSU-Chico Collections--Riffle

Benthic and drifting macroinvertebrates were sampled at four sites in this reach of the Feather River by CSU-Chico from river mile 47.2 to 58.5 in winter, spring, and summer 2002 (Appendix A-3). The dominant taxa at CSU-Chico sites in this reach were similar to DWR-sampled Feather River sites between the Fish Barrier Dam and Thermalito Afterbay Outlet. The macroinvertebrate assemblage in this reach of the Feather River was dominated by midges (Diptera:Chironomidae), baetid mayfly nymphs (Ephemeroptera:Baetidae), hydropsychid caddisfly larvae (Trichoptera:Hydropsychidae), mites (Oribatidae:Oribatid), and black flies

(Diptera:Simuliidae). Data from the CSU-Chico study indicate that macroinvertebrate densities varied substantially between seasons.

The number of cumulative taxa at each site within this reach ranged from 18 to 31, with the lowest and highest taxa richness observed at the MacFarland site (river mile 53.5). The cumulative number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa was relatively uniform across all four sites (3 to 5 taxa). SDI values in this reach also were fairly uniform, ranging between 1.7 and 2.1 among all sites between the Thermalito Afterbay Outlet and Honcut Creek. Winter and spring collections generally had lower diversity compared to summer in this reach of the Feather River. As with DWR riffle sampling, collectors and filterers were the most abundant functional feeding groups during all seasons and at all sites.

5.1.6 Oroville Wildlife Area

DWR Collections--Riffle

Macroinvertebrate communities sampled in the riffle site in the Oroville Wildlife Area were similar in diversity and composition to those of sites in the Feather River between the Fish Barrier Dam and Honcut Creek (Appendix A-2). The number of cumulative taxa (28 taxa), Shannon Diversity Index (2.3), and cumulative number of EPT species (10 taxa) were similar to other Feather River sites between the Fish Barrier Dam and Honcut Creek. The macroinvertebrate community at this site was dominated by collectors (56 percent), filterers (20 percent), and grazers (19 percent). Shredders were not found at this site.

DWR Collections--Submerged (Ponar)

Deeper-water sampling in the Oroville Wildlife Area showed a less diverse macroinvertebrate assemblage than sampling with a kick screen and metal frame (Appendix A-2). Six cumulative taxa were collected during submerged sampling at Mile Long Pond. One individual of one EPT species, *Caenis sp.* (Ephemeroptera :Caenidae), was collected during sampling. The submerged sample was dominated by midges (Diptera:Chironomidae) and aquatic worms (Oligochaeta).

5.1.7 Lower Feather River Downstream of Honcut Creek

Macroinvertebrates in this reach were sampled in riffles at three sites and with a ponar grab at two sites. Riffle samples collected in this reach of the Feather River contained macroinvertebrate densities one to two orders of magnitude higher than those sampled from deeper water with ponar grabs.

DWR Collections--Riffle

Appendix A-2 provides summary information and biological metrics that were used to support impact assessment at each of the three stations in this reach. Midge (Diptera:Chironomidae) and blackfly (Diptera:Simuliidae) larvae, baetid mayfly nymphs

(Ephemeroptera:Baetidae), and hydropsychid caddisfly larvae (Trichoptera:Hydropsychidae) were present at all three stations. Mayflies (Ephemeroptera:Ephemerelidae and Leptohyphidae) , moths (Lepidoptera:Pyralidae), caddisfly taxa from two additional families in the Order Trichoptera (Hydroptilidae, Glossosomatidae), mites (Trombidiformes:Lebertidae), and aquatic worms (Oligochaeta) also were found at all sites in lower densities.

The macroinvertebrate community of all the DWR stations in the Feather River downstream of Honcut Creek included many taxa that are important prey of the fish species in the river. These taxa include all the true flies (Diptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). Stoneflies (Plecoptera) were not present at riffle sites within this reach.

The numbers of cumulative taxa at three riffle sites within this reach were similar; ranging from 22 to 24, with the highest taxa richness located at the site upstream of Archer Avenue. The cumulative number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa was relatively uniform across all sites in this reach (10 to 15 taxa). The site near Shanghai Bend Falls had the lowest number of EPT taxa. SDI values in this reach were similar, ranging between 1.6 and 2.1 among all riffle sites in this reach. Tolerance indices and diversity indices were similar for DWR sampling sites in this reach compared to reaches located between the Fish Barrier Dam and Honcut Creek.

Collector and filterer functional feeding groups were dominant at all three sites in this reach. No shredders were collected in this reach and predators were observed infrequently.

<u>DWR Collections--Submerged (Ponar)</u>
Deeper-water sampling at two Feather River sites below Honcut Creek showed a less diverse macroinvertebrate assemblage than riffle sampling with a kick screen and metal frame (Appendix A-2). Three cumulative taxa were collected during submerged sampling at sites near Verona and upstream of the Yuba River confluence. Midges (Diptera:Chironomidae) and clams (Veneroida:Corbiculidae) comprised greater than 95 percent of the collected sample at both locations. One individual of one EPT species, *Atenella soquele*, (Ephemeroptera :Ephemerellidae), was collected during underwater sampling at the site upstream of the Yuba River confluence.

5.1.8 Sacramento and Yuba Rivers

<u>DWR Collections--Submerged (Ponar)</u>
Macroinvertebrate communities in the Sacramento and Yuba Rivers differed substantially from each other (Appendix A-2). Deeper-water sampling in the Sacramento River above the Feather River confluence showed a community dominated by midges (Diptera:Chironomidae). Only three taxa were observed at this site. In the

Yuba River, ponar grab sampling indicated that 15 taxa were present, with a macroinvertebrate community dominated by midges (Diptera:Chironomidae), aquatic worms (Oligochaeta), and mayflies (Ephemeroptera:Leptophidae).

5.2 PHYTOPLANKTON

Phytoplankton data collected by DWR were available from 14 sites and are presented in Appendix B. Total counts of phytoplankton by taxonomic group and geographic area are provided in Table 5.2-1.

Table 5.2-1 Total count of phytoplankton, by taxonomic group and geographic area, for sites sampled by DWR in 2002.

	Geographic Area				
Organism Type	**Entire Study Area**	**Lake Oroville**	**Thermalito Complex**	**Downstream of Oroville Dam**	**Oroville Wildlife Area**
Blue-green	322	89	70	9	78
Cryptomonads	312	81	63	9	76
Diatoms	1,563	578	834	50	83
Dinoflagellates	60	20	5	4	18
Euglenoids	31	11	1	1	13
Flagellates	248	17	14	4	4
Greens	411	76	96	25	209
Yellow-browns	135	81	46	3	5
Yellow-greens	489	3	0	0	0
Total	3,571	956	1129	105	486
Number of Sites	14	5	4	2	3

Source: DWR sampling data 2002-2003

5.2.1 Entire Study Area

Phytoplankton data were collected at 14 sites by DWR from Lake Oroville, Fish Barrier Pool, Thermalito Complex, and Oroville Wildlife Area in fall 2002. Phytoplankton communities were dominated by diatoms (57 percent), followed by green algae (16 percent), Cryptomonads (9 percent), and blue-green algae (9 percent) (Appendix B).

5.2.2 Lake Oroville

Diatoms were the most abundant group of algae present at five sampling locations in Lake Oroville (Appendix B). *Aulacoseira granulata, Fragilaria crotonensis, and Asterionella formosa* were the most common species, comprising 73 percent of the diatoms among the five sites. Blue-green algae (9 percent), green algae (8 percent), yellow-brown algae (8 percent), and cryptomonads (8 percent) were less prevalent in Lake Oroville than diatoms (Appendix B).

5.2.3 Thermalito Complex and Fish Barrier Pool

The plankton community in this geographic region was similar to that in Lake Oroville. Diatoms were the most prevalent group (72 percent), followed by green algae (10 percent), cryptomonads (6 percent), blue-green algae (6 percent), and yellow-brown algae (4 percent) (Appendix B).

5.2.4 Oroville Wildlife Area

The plankton community in the OWA was dominated by green algae (43 percent). The most common species were *Oocystis sp.* and *Closterium sp* (Appendix B). Blue-green algae (17 percent), diatoms (16 percent), and cryptomonads (16 percent) were present in lesser abundance. All other phytoplankton taxa represented less than 10 percent of the total sample in the OWA.

5.3 ZOOPLANKTON

Zooplankton data collected by DWR were available from six sites and are presented in Appendix C. Zooplankton densities are summarized by taxa and geographic areas in Appendix C.

5.3.1 Entire Study Area

Zooplankton data were collected at six sites by DWR from Lake Oroville and the Thermalito Complex during 2002 and 2003 (Appendix C). Rotifers were the most prevalent group at all Lake Oroville stations, followed by Copepoda and Cladocera (Appendix C). At one site in the Thermalito Afterbay, copepods were the most common species, followed by cladocerans and rotifers.

5.3.2 Lake Oroville

Rotifers were the most prevalent group at all Lake Oroville stations. The most common species among all sites were *Keratella cochlearis* and *K. quadrata*. Other common species included *Polyarthra* sp., *Kellicotta longispina*, *Tichocerca* sp., and *Asplancha* sp. Two species of copepods, *Cyclops* sp. and *Leptodiaptomus tyrrelli,* were present in all samples from the five Lake Oroville sites. *Daphnia sp.* and *Bosmina longirostris* were the most prevalent cladocerans found in the reservoir.

5.3.3 Thermalito Complex

Cyclops sp. was the most prevalent copepod at the location in the Thermalito Complex (Appendix C). *Daphnia* sp. was the most prevalent cladoceran, while *Keratella* sp. dominated the rotifer assemblage.

6.0 ANALYSES

6.1 LITERATURE REVIEW ON NON-FISH AQUATIC RESOURCES

6.1.1 Effects of Environmental Disturbances on Aquatic Macroinvertebrate Communities

Prior to construction of Oroville Dam, the main stem of the Feather River that is presently inundated by the reservoir was free-flowing and inhabited by invertebrate groups adapted to riverine habitat. Under natural hydrologic cycles, flow was high in the winter and spring and lower in the summer and fall. Natural floods flushed sediment downstream and created interstitial spaces in the stream gravel and cobble substrates that provided habitat for stream invertebrates. Erman (1996) writes that change in Sierra Nevada ecosystems arrived with the construction of dams, diversions, roads, and other barriers. Impounded waters of the Sierra Nevadas developed very different invertebrate communities. As Erman notes, “there is no, or almost no, similarity between invertebrate assemblages in running water and those in standing water.” Major taxa of many invertebrate groups can be found in both free-flowing and impounded waters, but species composition usually is different.

No systematic statewide surveys of California aquatic invertebrates have been conducted (Erman 1996), though data are available from many areas from a variety of disparate sources. The currently available data are from regional studies only.

6.1.1.1 Measures of Biotic Health for Macroinvertebrates

Macroinvertebrate communities have been used widely as indicators in the assessment of stream and reservoir health. A variety of techniques have been used to characterize macroinvertebrate communities. Many current invertebrate assessments in California are conducted according to modifications of the USEPA protocol. Stream health is usually determined by the species diversity of the assemblage present or through groupings at higher taxonomic levels. Negative impacts resulting from environmental shifts or anthropogenic impacts are shown by decreasing species diversity, organism size, or changes in taxonomic composition (Erman 1996). Macroinvertebrate communities integrate long-term effectors in stream habitats, which provides a distinct advantage over measurement of chemical or physical parameters that may change rapidly from one sampling visit to another.

Multimetric indices have been used for assessing the biological integrity of macroinvertebrate communities in lotic systems because they simplify and condense biological data, thus allowing rapid comparisons of communities from different locations (Barbour *et al.* 1995, Resh and Jackson 1993, Simon and Lyons 1995). Multimetric indices have been widely used for rivers (Ohio USEPA 1987, DeShon 1995, Barbour *et al.* 1999, Plafkin *et al.* 1989), but less often for lakes, to assess ecosystem health.

Components of these indices include data classification into formats that show taxa richness, relative abundance, tolerance measures, and feeding measures. These metrics are described in further detail below.

Taxa richness, or the number of distinct taxa, represents the diversity within the aquatic assemblage (Resh *et al.* 1995). Richness measures have been evaluated at the species level or in designated groupings of taxa, often as higher taxonomic groups. Increasing diversity generally correlates with increasing health of the assemblage and suggests that niche space, habitat, and food sources are adequate to support survival (Barbour *et al.* 1999). Taxa richness is the key element in indices such as the Invertebrate Community Index (ICI) (DeShon 1995), fish Index of Biotic Integrity (IBI) (Karr *et al.* 1986), and benthic Index of Biotic Integrity (Kerans *et al.* 1992, Kerans and Karr 1994), and is used in Rapid Bioassessment Protocols (RBP) (Plafkin *et al.* 1989).

The relative density of taxonomic groups within an assemblage has given insight into the status of aquatic invertebrate communities and the ecological patterns that act on them. Healthy and stable aquatic invertebrate assemblages should be relatively consistent in their proportional composition (Barbour *et al.* 1999). Measures of composition have been useful when evaluating the impacts from nuisance or exotic species or for understanding the interaction among taxonomic groups.

Tolerance measures have been applied to better understand the level of perturbation on aquatic invertebrate assemblages, usually from pollution or habitat degradation (Barbour *et al.* 1999). Metrics such as the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987, 1988) and Biotic Condition Index (Winget and Mangum 1979) have been used to detect problems with organic pollution and sedimentation, respectively. Tolerance measures may be independent of taxonomy or applied to specific taxa groups.

Feeding measures consist of functional feeding groups and provide information on feeding strategies in the aquatic invertebrate community (Barbour *et al.* 1999). The most common type of feeding measure involves separating sampled organisms into functional feeding groups (guilds) of scrapers, shredders, gatherers, filterers, and predators. Stable stream and reservoir ecological systems reflect a diversity of feeding guilds and usually contain specialized feeders (e.g., scrapers, shredders, and piercers). An imbalance of generalists (e.g., collectors and filterers) compared to specialized feeders usually reflects disturbed conditions because generalists are less susceptible to pollution and habitat alteration (Barbour *et al.* 1999). Segregation of sampled organisms by feeding guilds is difficult because proper assignment to functional feeding groups is necessary, a process that can be difficult, costly, and time consuming. Thus, the usefulness of these measures has been contested in many studies (Erman 1996, Barbour *et al.* 1999).

Although rapid assessment approaches are usually cost effective and provide an understandable result to a diverse audience, limitations can reduce their effectiveness.

One major disadvantage to most monitoring studies is their lack of repeated sampling (i.e., documentation of long-term environmental variability) (Rosenburg and Resh 1993). Other disadvantages are that taxa are generally not identified to species and imprecise assignment of taxa (usually genera or family) to functional feeding groups can occur (Erman 1996).

6.1.1.2 General Effects of Dams and Barriers on Macroinvertebrate Communities

Altered flow regimes can have significant impacts on macroinvertebrate communities. Flow regulation can result in decreased magnitude of temperature fluctuations compared with natural conditions, interruptions in the cycling of nutrients, food, and sediment, and alterations in the geomorphological characteristics of the river (BioWest, Inc. 2003). Altered seasonal flow patterns also can change seasonal temperature regimes in the rivers below dams by providing cooler temperature water in the summer and warmer temperature water in the winter. Changes in the seasonal timing of the flow and temperature regimes can impact life history characteristics of individual aquatic species, which in turn affects the composition of communities. Adverse impacts to invertebrate communities usually result in a decrease in organism size and a decrease in diversity, depending on the degree of impact (Erman 1996). In many cases, altered tailwater habitats may favor a select number of species (especially the mayfly, *Baetis*), resulting in a community where high numbers of fewer species are present. Dipteran and worm populations generally increase in abundance in tailwater release areas, while diversity of mayfly, stonefly, and other benthic orders can be significantly reduced (BioWest, Inc. 2003). Information is summarized below for two river systems affected by altered flow regimes to provide examples of the potential impacts of such changes on macroinvertebrate communities.

<u>Green River below Flaming Gorge:</u> In the Green River, a principal tributary to the Colorado River, Flaming Gorge Dam has dampened the natural hydrograph and altered the natural temperature regime (Vinson 2001). The pre-dam community had densities that were relatively low at about 1,000 organisms/m^2, and 60 to 80 percent of the community was comprised of mayfly taxa. After dam construction, overall macroinvertebrate densities increased and there was a resulting decrease in macroinvertebrate diversity. Midges and blackflies dominated the community and mayfly taxa were severely reduced after modification of the natural hydrograph. Vinson (2001) determined that the warmer winter and cooler summer water temperatures resulting from the dam operation played a role in reducing diversity. Vinson also noted that high densities of some species in the post-dam environment prevented some species from recolonizing the area below the dam and that the dam inhibited drift from upstream areas.

<u>San Juan River below Navajo:</u> In the San Juan River below Navajo Reservoir in Utah, similar alterations in the temperature regime of the river below the dam impacted benthic communities. Holden *et al.* (1980) noted that sampling locations closest to the

dam contained the highest macroinvertebrate densities and the lowest diversity. Mayflies, caddisflies, and stoneflies were poorly represented in the 13 miles of stream downstream of the dam, but increased in abundance at stations further downstream in the San Juan River. The communities at the base of the dam were dominated by midges, blackflies, and worms (Dubey 1996).

6.1.1.3 Effects of Ramping Rates on Macroinvertebrate Communities

Discharge changes resulting from hydroelectric peaking directly affects water levels, water temperatures, and flow velocities and can alter benthic macroinvertebrate and fish abundances and distributions (Brusven and MacPhee 1976). Fluctuating water levels from dams also can stimulate invertebrate drift downstream (Minshall and Winger 1968, Brusven and Trihey 1978, Bovee 1985) or strand invertebrates as water levels are lowered suddenly and stream channels dry up (Erman 1996). Stranding of benthic insects during rapid drawdown have been shown to cause detrimental effects at higher trophic levels (Kroger 1972). For example, extreme reductions in flow in the tailwater of Dworshak Dam on the Clearwater River, Idaho, significantly increased the amount of insect drift and the rate of ingestion by salmon in the diversion channel (Brusven and MacPhee 1976). In addition, downstream shorelines experiencing daily fluctuations from dam releases were not readily colonized by stoneflies, mayflies, and caddisflies; chironomid midges were the most resilient stranded insects in these unstable areas and the first ones to recolonize the flooded areas (Brusven and MacPhee 1976).

6.1.1.4 Patterns of Macroinvertebrate Migration and Recolonization

The aquatic stages of most stream insects involve short migration distances (less than 300 m). These migrations are important ecologically as a means for genetic dispersal and the insects' stream-colonization cycle (Vaughan 2002). Migrations can occur along the substrate or via drift. Drift has been shown to be an important dispersal mechanism for many macroinvertebrates (Benson and Pearson 1987). Not surprisingly, increased macroinvertebrate drift can be correlated with higher stream flows (Williams and Williams 1993), although in some systems, extreme reductions in discharge below hydropower projects have stimulated insect drift (Brusven and MacPhee 1976). Drift also can be associated with diel periods. In the Clearwater River, Idaho, numbers of drifting insects were greatest at night (Brusven and Trihey 1978). Extreme scouring flows or severe hydropower peaking can affect macroinvertebrates by altering migration patterns and preventing colonization on substrates. In summary, macroinvertebrate drift is characteristic of populations in running water and plays an important ecological role by providing a mechanism for recolonization of disturbed areas and by providing increased food for predators (Merrit and Cummins 1996).

In addition to drift, aquatic invertebrates have evolved several methods to recolonize disturbed areas, including swimming, crawling, and flight (MacKay 1992). Most aquatic insects are able to fly upstream during their adult phase, but large barriers such as large waterfalls and dams prevent migration along the stream corridor for most species. Surface barriers may also be associated with degraded water quality and may concentrate predators (Vaughn 2002). Several studies have documented shifts in the relative contribution of functional feeding groups associated with small stream barriers (e.g., culverts) (King *et al.* 2000, Vaughn 2002).

Recolonization experiments in lotic systems have shown that streams are patchy environments. Abiotic factors such as season, water temperature, substrate, and discharge were important in colonization and thus determined the structure of the benthic community (Moser and Minshall 1996). In a third order Rocky Mountain stream in Idaho, colonization of the benthic community through drift was important in spring when water temperature and algal resources were low and discharge was high (Moser and Minshall 1996). In summer and fall, when water temperatures were high, discharge was low, and algal resources were abundant, drifting and crawling taxa colonized equally rapidly (Moser and Minshall 1996), suggesting that certain modes of colonization can vary in importance on a seasonal basis and can depend on the ambient environment. In this experiment, drifting invertebrates that were competitively inferior in one patch during spring could avoid competition and access alternative habitats by moving to areas less accessible to some members of the assemblage (Moser and Minshall 1996).

6.1.1.5 Effects of Fish on Macroinvertebrate Communities

Fish predation does not appear to control macroinvertebrate communities in all streams, although many studies have shown that fish do alter aspects of macroinvertebrate communities. Experimental removal of trout in Rocky Mountain streams showed that macroinvertebrate densities were not significantly different between natural and predator removal streams (Allan 1982). Power (1990) showed that predatory fish in the Eel River, California, affected predatory invertebrates, which in turn controlled the abundance of larval chironomids. In many of the reported field experiments relating to fish predation and macroinvertebrates, fish impacted communities by their size-specific feeding habitats, typically resulting in the depletion of larger individuals from the population and subsequent effects on community composition and numbers (Helfman *et al.* 1997).

6.1.1.6 Effects of Sediment on Macroinvertebrate Communities

Suspended sediment can interfere with the reproductive, respiratory, or feeding behavior of surface-oriented macroinvertebrates. Sediment may also interfere with drifting behavior via abrasion or elevated turbidity. Increased sediment can decrease available habitat for benthic macroinvertebrates by creating highly embedded stream substrates with no pore spaces available for invertebrate colonization (Erman 1996), as well as preventing clinger-type organisms from clinging to rock substrates. Suspended particles also are an important component of nutrient and energy cycling and transport in lotic systems (Whiles and Dodds 2002). Generally, as sediment increases, species richness, density, and biomass decrease (Johnson *et al.* 1993).

Studies on the direct effects of suspended or deposited sediment on macroinvertebrates indicate that the most common ones are abrasive action, loss of visual efficiency in feeding, interference in food gathering by filter-feeding insects (e.g., net-spinning caddisfly larvae), and decreases in abundance, biomass, survival, and productivity. Many sediment-invertebrate studies are associated with gravel dredging or mining operations. In general, these studies show decreases in abundance or biomass (Cordone and Kelley 1961, Forsage and Carter 1974, LaPerriere *et al.* 1983, Wagener and LaPerriere 1985) or altered feeding (Aldridge *et al.* 1987) as a result of increased suspended sediment levels in rivers. Brunskill *et al.* (1973) reported reductions in filter feeders as suspended sediment concentrations in the Mackenzie River, Canada became elevated. Indirect effects of sediment on macroinvertebrates include increases in invertebrate drift, presumably as a consequence of reduced light, and the adverse effects associated with the redeposition of sediment at high levels (Waters 1995).

Turbidity has been hypothesized to be a factor affecting macroinvertebrate movement and distribution. In southwestern North Carolina, turbidity, suspended load, and bed load were found to have significant effects on species richness and diversity in the insect community (Lemly 1982). Chironomids were found in high numbers in the zones receiving sedimentation (Lemly 1982). Taxa that were most affected by increased sedimentation were the filter feeding Trichoptera and Diptera. Predaceous Plecoptera and some Ephemeroptera taxa also showed decreased abundance and diversity associated with increased sediment levels and turbidity (Lemly 1982). Lemly (1982) notes that studies attempting to measure correlations between turbidity and macroinvertebrate drift often were confounded by unregulated light levels during the experiment (Doeg and Milledge 1991, Rosenberg and Wiens 1978, 1980); light is known to influence invertebrate movement. At least one study indicated that there was not a correlation with sediment and drift (O'Hop and Wallace 1983).

6.1.1.7 Effects of Temperature on Macroinvertebrate Communities

The ambient thermal environment affects the life history, development, and distribution of aquatic macroinvertebrates (Vannote and Sweeney 1980). Metabolism, growth, emergence, and reproduction are directly linked to water temperature whereas food availability may be indirectly linked with temperature regimes (Merritt and Cummins 1996). In shallow lakes or along shorelines, higher water temperatures can result in greater algal food supply and faster growth, but during summer these areas may be oxygen limited. Alteration of thermal regimes outside the optimal range for individual species can affect fitness by decreasing body size and fecundity (Merritt and Cummins 1996).

Invertebrate communities are affected by the modified temperature releases below hydroelectric facilities and by thermal pollution. The effects include, but are not limited to: (1) reduction in species diversity as a consequence of reduced temperature fluctuations; (2) more intense competition associated with greater productivity; (3) elimination of major invertebrate predators; and (4) failure of the limited temperature range to provide optimal temperatures for various physiological processes (Ward 1976). In a more general sense, altered regions below dams or in areas with thermal pollution with characteristic higher winter water temperatures and lower summer temperatures can fail to provide the thermal cues critical for life-cycle phenomena (Coutant 1968, Pearson et al. 1968, Nebeker 1971, and Lehmkulh 1972, 1974). In a study of thermal pollution in Fairfield Reservoir, Texas, Wellborn and Robinson (1996) reported there was no evidence to show that thermal effluents enhanced densities of macroinvertebrates during the winter, but effluents contributed to thermal stress of aquatic organisms during summer.

The composition of invertebrate communities below dams is dependent on patterns of emergence (i.e., maturation), which are highly affected by water temperature. One effect of water temperature on emergence is accelerated growth rates and premature emergence. An example of this is provided by Coutant (1968), who showed that a 1 °C increase in water temperature caused Hydropsychidae to emerge two weeks earlier in the Columbia River. In general, invertebrate species may be eliminated below dams if their growth rate is accelerated in the winter or decreased in the summer, resulting in premature or delayed emergence. Warmer temperatures in winter result in faster maturation and emergence into the terrestrial environment and may occur at a time that is not optimal. Invertebrates that emerge prematurely may encounter air temperatures lethal to aerial adults or experience decreases in productivity from inactivated mating mechanisms or because of nonsynchronous emergence of males or females (Ward 1976). Similarly, cooler temperatures in summer delay maturation, which also results in emergence at the wrong season; hence many organisms cannot survive and are eliminated below reservoirs. Water temperature also may cause shifts in community structure by having detrimental impacts on satisfying physiological requirements of certain species within the macroinvertebrate community. For example, the necessity of near freezing followed by higher temperatures to stimulate hatching may explain the absence of some mayflies below dams (Lehmkuhl 1972). In warm conditions, constant water temperatures may cause extended emergence for some species (Ward 1976). The ecological consequence of extended emergence for a species can be niche overlap, altered productivity, or increased life-cycle diversity.

6.1.2 Effects of Environmental Disturbances on Plankton Communities

6.1.2.1 Effects of Dams on Plankton

Phytoplankton are potentially important sources of energy for stream and, more especially, reservoir ecosystems. The abundance and distribution of these organisms in rivers and reservoirs are highly dynamic and are most affected by light, nutrients, temperature, flow, and presence of herbivores (Murphy 1998). Phytoplankton organisms vary widely in function and size, and are subject to large spatial and temporal variations in diversity and abundance (Wetzel 2001). Zooplankton provide a trophic link between the phytoplankton and higher trophic levels, particularly fish, and thus make available to fish the energy and nutrients produced by the phytoplankton. Like the phytoplankton, the zooplankton community is highly dynamic. Light, temperature, flow, availability of preferred phytoplankton species and presence of fish and invertebrate predators affect the distribution and abundance of zooplankton species (Wetzel 2001). A summary of specific potential effects on plankton communities associated with light, sediment, fish, water temperature, and nutrients is contained in the following sections.

6.1.2.2 Effects of Light on Plankton

One of the most important factors that limit primary production is light (Murphy 1998). Phytoplankton and other algae exhibit increased photosynthesis up to the level of light saturation. Habitats where light saturation may occur are along the surface of reservoirs, or in streams and ponds with limited shading from riparian vegetation. Light intensity has been shown to affect the rate of photosynthesis and, as a consequence, the rate of growth (Wetzel 2001). A considerable degree of adaptation can occur with changing light intensities and responses to light intensities are species-specific in many instances (Wetzel 2001). Many zooplankton species vertically migrate in the water column depending on light level. The vertical migrations serve to reduce vulnerability to visual predators, expose the organisms to metabolically optimal water temperatures, and locate concentrations of preferred phytoplankton food (Wetzel 2001).

6.1.2.3 Effects of Sediment on Plankton

Increased levels of suspended sediment can decrease water transparency and reduce photosynthesis (Waters 1995). Sediment also can abrade or suffocate periphyton and macrophytes (Waters 1995). Negative correlations between turbidity and primary production in rivers have been shown in several studies (LaPerriere *et al.* 1983, Pain 1987), but there is limited empirical evidence that shows stream communities are damaged through reduced photosynthetic rates (Waters 1995). Organic matter from sediments also has been shown to provide seasonal inputs of nutrients into the ecosystem, which can subsequently cause seasonal variations in phytoplankton blooms (Cloern *et al.* 1983). The effects of turbidity are often difficult to distinguish from other environmental variables that may affect rates of primary production, such as water temperature and nutrient concentrations.

Turbidity in reservoirs from clays and silt may also suppress zooplankton growth and productivity by direct interference mechanisms (Wetzel 2001). In cladocerans, mechanical interference of suspended clay particles reduced feeding rates and thereby suppressed growth and reproduction (Kirk 1992). Suspended clay also suppressed growth and reproduction of ciliates, but had minimal effects on other plankton groups (Hart 1986, Jack and Gilbert 1993). Turbidity in reservoirs also may affect the community structure of zooplankton (Kirk and Gilbert 1990, Kirk 1991, Cuker and Hudson 1992). Filter-feeding zooplankton species can be negatively affected during flooding events, as algal resources are sparse in proportion to more abundant silt particles (Kirk 1992).

6.1.2.4 Effects of Fish on Plankton

Fish can impact the trophic structure in reservoirs and rivers. Planktivorous fish have been shown to feed selectively on larger zooplankton, effectively causing a shift in community structure toward smaller-sized zooplankton (Helfman *et al.* 1997). Planktivorous fish also have been shown to affect the diel vertical migrations of zooplankton, their age at sexual maturity, and the average size of offspring (Helfman *et al.* 1997). Fish also have an important role in cycling nutrients in rivers and reservoirs. Because zooplankton feed selectively on phytoplankton, shifts in zooplankton community structure can influence phytoplankton species composition and primary production (Scheffer *et al.* 2000). Conceptual models that have been proposed to describe this complex trophic interrelationship include the trophic cascade model (Shapiro and Glass 1975, McQueen 1990). There is a high level of scientific support to suggest that phytoplankton composition and abundance is influenced by zooplankton and fisheries assemblages, although the exact nature of these effects is often dampened by confounding environmental variables (Reynolds 1999).

Fish generally crop no more than 5 to 10 percent of zooplankton production annually, although more severe impacts have been observed (Helfman *et al*. 1997). For example, alewives and yellow perch consumed 97 percent of the zooplankton production in Lake Michigan in 1984 (Evans 1986). If fish predation intensity is very high, it may be the main determinant of zooplankton production and community structure, but phytoplankton productivity and water quality are more typically the main determinants(Vanni and Findlay 1990, Hessen *et al.* 1995).

Effects of planktivorous fish on zooplankton are related to the production rates of the fish. In general, fish production in reservoirs is highly variable and species specific. For example, salmonids have been shown to have annual production rates from 0.21 to 66 kilograms per hectare per year (kg/ha/yr) from standing waters (Bisson and Bilby 1998). In comparison, annual production estimates of cyprinids (minnows and carp) have been documented as high as 1,000 kg/ha/yr, at least an order of magnitude higher than salmonids (Bisson and Bilby 1998). In part this difference is related to the fact that the cyprinids inhabit warmer and more productive waters than the salmonids.

McQueen (1990) reviewed reservoir manipulation studies to identify trends in fish/plankton interactions. This review found that effects on plankton communities by fish are seen more often in shallow lakes or in situations where fish communities are strongly manipulated. Plankton dynamics in deep lakes are controlled more by water quality and other factors than by fish predation (McQueen 1990). McQueen (1990) also noted that there was no predictable evidence for fish/plankton interactions.

6.1.2.5 Effects of Reservoir Phytoplankton and Zooplankton Distributions on Communities of Receiving Streams

Reservoir plankton populations provide an important source of food for populations of fish and macroinvertebrates in downstream river reaches (Lieberman *et al.* 2001). Temperature control devices and their effect on particulate organic matter and plankton downstream of Shasta Dam were investigated recently in the Sacramento River, California (Lieberman *et al.* 2001). Downstream of Shasta Dam, epilimnetic withdrawals from January to mid-June, and mid-level withdrawals through August resulted in localized increases in small particulate organic matter at Shasta Dam tailwaters and increases in phytoplankton and zooplankton biomass, as well as an increase in biotic diversity. This is consistent with other research that shows tailwaters usually contain a high density of lentic phytoplankton and zooplankton that decreases rapidly with distance from the outfalls (Hynes 1970, Novotny and Hoyt 1982). Ward and Wetzel (1975) observed that dams that release water from the hypolimnion typically have smaller impacts to downstream communities compared with dams that release water from the epilimnion. Lieberman *et al.* (2001) noted that these changes potentially affect the food base of the Sacramento River and therefore could affect threatened and endangered species or specific races of Chinook salmon.

6.1.2.6 Effects of Nutrients on Phytoplankton and Zooplankton Communities

Phytoplankton and zooplankton communities in reservoirs and rivers are affected by the nutrient content of the water, particularly levels of nitrogen (N) and phosphorus (P). The literature suggests that both elements can limit or increase aquatic primary production, depending on the concentrations and ratio of the two elements present in the ecosystem. The mechanisms governing the nutrient/biotic interaction are often unclear (Reynolds *et al.* 2001). However, P often will be the first nutrient to become limiting because it is usually less abundant than N (Wetzel 2001). Numerous laboratory (O'Brien and DeNoyelles, Jr. 1974, Currie and Kalff 1984) and field studies (Dillon and Rigler 1974, Patterson *et al.* 1997) have investigated the N:P ratio and other chemical relationship in lakes and their impacts to phytoplankton and zooplankton species. Nutrient loading in stream and reservoir systems commonly occurs from runoff associated with agricultural operations. In addition to increases in primary production, nutrient-rich effluents have been shown to affect the size of plankton. For example, after additions of effluent to an agricultural area in Israel, plankton assemblages were dominated by larger species without a corresponding change in total abundance (Teltsch *et al.* 1992).

Other nutrients such as carbon and silica have been shown to limit aquatic primary production. In streams, carbon is usually found in sufficient quantities because of water turbulence and high carbon dioxide solubility (Wetzel 2001). Silica is a required material for diatoms, but not for most other algae (Werner 1977). Spring blooms of diatoms in rivers and reservoirs may deplete available silica, leading to shifting community structure dominated by species that do not require silica (Murphy 1998, Wetzel 2001).

It is clear that nutrient composition is important for determining assemblage structure in plankton, but many studies have documented the difficulty in explaining population responses directly with nutrient concentrations. Reynolds (1998) points out that the ecological factors that drive changes in plankton abundance and composition are varied, complex, and are not fully understood. Modeling approaches have been useful in researching the community ecology of plankton, but generally fail to predict biomass growth because of confounding environmental factors. These models have inputs of plankton functional groups, swimming and settling rates, grazing rates, and nutrient and light inputs (Reynolds 1999, Reynolds *et al.* 2001).

In lakes, phytoplankton communities typically exhibit regular annual periodicity as a result of seasonal changes in nutrient concentrations (Barbiero *et al.* 1999). As the year progresses, competition for increasingly scarce nutrient supplies results in changes to the community composition (Barbiero *et al.* 1999). Disturbances, such as wind or storms, typically return some nutrients to the water column, thereby permitting some species to recolonize habitats. This may lead to temporary increases in species richness as representatives of earlier successional stages respond to the change in nutrient supply (Barbiero *et al.* 1999). For zooplankton, lake productivity has been shown to affect species distribution in rivers and lakes (Wetzel 2001). Field surveys of Florida lakes indicated that zooplankton abundance is significantly higher in eutrophic systems compared to oligotrophic systems (Blancher 1984). Eutrophic systems were dominated by rotifers and often experienced highly variable fluctuations in abundance. Oligotrophic systems were dominated by copepods and populations were more stable.

6.2 EVALUATION OF CURRENT PROJECT EFFECTS

6.2.1 Macroinvertebrates

The biological metrics that were used to evaluate current project effects on macroinvertebrates provide an index of ecosystem impairment, but do not necessarily provide any information about what the specific impairment is. Most biological metrics are linked with water quality and are based on several key tenets, such as diverse macroinvertebrate communities are indicative of less impaired ecosystems than less diverse communities, and communities composed of the highest percentage of pollution intolerant taxa are indicative of the least impaired ecosystems. Where appropriate, we have provided detail on specific ecological mechanisms that may influence biotic integrity, but we note that in many cases, multiple ecological factors and/or mechanisms contribute to, or have the potential to affect ecosystem health.

6.2.1.1 Effects of Oroville Dam and other Project Barriers on Macroinvertebrate Communities

Evidence of significant habitat alteration from mining, agriculture, and other anthropogenic impacts has been documented in the Feather River prior to construction of the Oroville Facilities. Habitat changes resulted in declines in salmonid abundance and generally had deleterious impacts to aquatic habitat. Although historical information on macroinvertebrate communities in the Feather River prior to construction of project facilities was not available, we consider it likely that current macroinvertebrate communities are structured differently than the post-Project communities. Organisms more tolerant to pollution and those that tolerate high sediment environments likely became more abundant as perturbations increased in the early 1900s. As human impacts increased, the Feather River likely supported a higher abundance of fewer species. Impacts of the Oroville Facilities on macroinvertebrates have likely been similar to those of dams in other large rivers. Flow alterations in the Feather River dampened the natural hydrograph, which likely decreased the incidence of flushing flows, reduced the magnitude of temperature fluctuations, interrupted cycling of nutrients, food, and sediment, and altered the geomorphic characteristics of the river.

Two case studies described in Section 6.1.1.2, General Effects of Dams and Barriers on Macroinvertebrate Communities, suggest that prolonged temperature and flow alterations in the Feather River below Oroville Dam likely impacted macroinvertebrate communities. Warmer winter temperatures and colder summer water resulting from regulated discharge may have affected individual species' life cycles and decreased overall species diversity near the dam. Recent sampling in the Feather River concurs with the aforementioned case studies. Based on diversity indices and taxa richness, data indicates that macroinvertebrate communities immediately downstream of the dam (riffle sampling from sites upstream and downstream of the Feather River Hatchery and ponar sampling near the Fish Barrier Dam) have lower measures of diversity compared to Feather River sites further downstream in the reach between the Fish Barrier Dam and Thermalito Afterbay Outlet. The sites nearer the fish barrier dam contain a high abundance of Chironomids. However, although diversity was slightly lower near the dam, results did not otherwise show a any relationship between diversity and distance from the dam.

A direct impact to macroinvertebrate communities has occurred in the inundation zone of Lake Oroville. Reservoir fluctuations prevent macroinvertebrates from colonizing these areas. Samples from a riffle at the site in the inundation zone showed substantially lower diversity and numbers of EPT taxa than samples from other sites in areas upstream of the Lake Oroville inundation zone. The most abundant species at the site within the inundation zone were midges (Diptera:Chironomidae), followed by caddisflies (Tricophtera:Hydropsychidae). These taxa typically are indicators of organic pollution (Harrington and Born 2000).

The macroinvertebrate and plankton communities downstream of the Fish Barrier Dam and in areas upstream of the Lake Oroville inundation zone appear to provide a relatively stable food base for fisheries resources. Benthic macroinvertebrate communities in the Feather River downstream of the Fish Barrier Dam and in areas upstream of Lake Oroville had high percentages of filterers, suggesting that plankton is not limiting in these waters. Receiving waters below dams typically have high numbers of plankton if surface withdrawal devices are used. Feather River sites upstream of the Lake Oroville inundation zone may have plankton densities comparable to downstream sites because most of the tributaries to Lake Oroville have dams in the headwater reaches. Results from recent field collections also support the assertion that food is not a limiting factor for fish in the Project area, as many taxa typically considered prey for fish (stoneflies, true flies, mayflies, and caddisflies) were present at all sampling sites.

6.2.1.2 Effects of Ramping Rates and Changes in Flow on Macroinvertebrate Communities

Construction of the Oroville Facilities and subsequent operation to minimize ramping has dampened the range of flows historically present in the Feather River. In the Feather River reach between the Fish Barrier Dam and Thermalito Afterbay Outlet, a minimum flow of about 600 cfs is maintained to aid anadromous salmonids. Downstream of the Thermalito Afterbay Outlet, flow fluctuations are more variable than in the reach between the Fish Barrier Dam and Thermalito Afterbay Outlet, but extreme flows also have been dampened by operation of the Project. Evaluating impacts to macroinvertebrates from flow regulation in the Feather River is difficult because historical data were not available. Thus, we were not able to evaluate from recent collections whether macroinvertebrate size had decreased, whether community structure had changed, or whether macroinvertebrate densities had changed over time. Based on previous studies in regulated rivers, altered tailwater habitats may favor a select number of species (especially the mayfly, *Baetis*), resulting in a community where high numbers of fewer species are present. Dipteran and worm populations generally increase in abundance in tailwater release areas, while diversity of mayfly, stonefly, and other taxonomic groups can be significantly reduced (BioWest, Inc. 2003). Recent field collections in the Feather River did not support the theoretical macroinvertebrate community response expected from large dams and flow regulation. Instead the benthic macroinvertebrate community in the Feather River varied little from the Fish Barrier Dam to Honcut Creek based on dominant taxa and diversity measures, suggesting that flow management operations in the Feather River are either not substantially affecting macroinvertebrate community structure, migration patterns, and colonization in the Feather River below Oroville Dam, or that macroinvertebrate communities have adapted to the current operational regime. The presence of many taxa that are known prey for fish and the high percentage of filterers throughout the project area suggests that flow regulation is not limiting food availability.

6.2.1.3 Morphology of the Feather River

The reach of the Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet contains relatively large areas of armored substrates. Substrate armoring in this segment has resulted from high-velocity flows transporting gravels downstream of this reach and a corresponding lack of gravel recruitment from upstream sources. Recent data collection indicates that macroinvertebrate communities immediately downstream of the dam (riffle sampling from sites upstream and downstream of the Feather River Hatchery and ponar sampling near the Fish Barrier Dam) have lower measures of diversity compared to other Feather River sites in the reach between the Fish Barrier Dam and Thermalito Afterbay Outlet and contain a high abundance of Chironomids. Collectors and filterers generally dominate the macroinvertebrate assemblage at these sites. The composition of the macroinvertebrate community at sites near armored areas is characteristic of habitats with disturbed substrates and flow regimes (i.e., higher abundance of fewer species and lower diversity).

6.2.1.4 Water Quality

Data from DWR and CSU-Chico collected in 2002 and 2003 indicate that macroinvertebrate communities throughout the Project area are composed of similar species, suggesting that water quality is fairly uniform among sites. Species of midges (Diptera:Chironomidae), blackflies (Diptera:Simuliidae) and baetid mayflies (Ephemeroptera:Baetidae) were present in moderate to high densities at most sites. Chironomid larvae usually live in the substrate where they build cases of sand or mud. Baetid nymphs are able to flourish in high flows because of their swimming ability. They often are one of the first species to recolonize disturbed areas. Blackfly larvae are typically found in high flows attached to rock surfaces. All three taxonomic groups contain genera that tolerate sedimentation and nutrient enrichment. Aquatic worms (Subclass Oligochaeta) also were found at most sites in the study area. These organisms are usually found in the highest numbers in slow-moving to standing waters with silt or mud substrates. Although the above taxa are often used as indicators for organic pollution and sedimentation, the presence of these organisms alone do not necessarily indicate significantly impaired water quality because these taxa typically are widespread in rivers throughout the Sacramento Basin. The presence of taxa that are more tolerant of pollution and sites that contain low species diversity, however, may indicate areas where water quality is limiting for macroinvertebrates. Based on macroinvertebrate diversity indices i the Feather River, the sites upstream of the Feather River Fish Hatchery and above Honcut Creek are possible locations where water quality may be affecting the macroinvertebrate community.

Construction of the Oroville facilities blocked upstream passage of salmonids above the Fish Barrier Dam, and in doing so, blocked import of marine-derived nutrients into the upper tributaries. However, at least on the North and South forks of the Feather River, dams existing prior to construction of the Oroville Facilities had already eliminated upstream salmon runs and, hence, “marine-derived” nutrients to these rivers. All other significant tributaries have impassable barriers usually very near the inundation zone of Lake Oroville, except the West Branch, which may have passable barriers at some flows (DWR 2004a). Therefore, effects to nutrient deprivation from the Oroville Facilities for macroinvertebrate productivity is generally restricted to the limited stream reaches upstream from the inundation zone before impassable barriers are encountered. Reductions in nutrients, such as nitrogen and phosphorus, reduce benthic algae and microbes in streams, and thus decrease food sources for stream grazers. Recent research suggests that inputs of marine-derived nutrients from salmon carcasses contribute to the productivity and diversity of benthic macroinvertebrate communities of streams where salmon spawn. In controlled experiments with streamside troughs, higher phosphorus concentrations have been shown to increase baetids, nemourid, and perlodid stoneflies and tricopterids (Quamme and Slaney 2003). Elimination of salmon carcasses may have a more direct effect on some dipteran species and other benthic invertebrates that are major carrion consumers.

Early accounts described runs of spring-run and fall-run Chinook salmon in the Feather River as " very heavy" (Clark 1929). However, as a result of hydropower and debris dams on the upper Feather River and its tributaries, as well as over-fishing and other human-induced impacts, the runs had been substantially reduced by the time the Oroville Facilities were built. Although historical information is not available on macroinvertebrates in tributaries to Lake Oroville, it is likely that the macroinvertebrate communities in the lower reaches of these streams, which were accessible to anadromous salmonids before the Project was built, have been affected by the elimination of the salmonids. The estimated potential losses of nutrients and organic matter from salmon blockage are substantial, but the significance of the losses has been difficult to evaluate because of limitations in the available information, including imprecision of the estimates for potential spawning densities and insufficiently low detection levels for measured nutrient concentrations in the upstream tributaries (see

SP-F8), though more recent data are available for low level nutrient concentrations in the tributaries upstream from Lake Oroville.

Values for the California State Bioassessment Procedures metrics and tolerance values computed from benthic macroinvertebrates collected at the DWR and CSU-Chico sites were in the middle-to-low part of the range (3 to 6), suggesting that conditions in the study area are slightly disturbed. The rating of slightly disturbed is supported by two additional metrics, percent tolerant taxa and percent intolerant taxa. The percentage of intolerant taxa was consistently low (less than 15 percent) across all sites except Fall River and Glen Creek. The percentage of tolerant taxa also was low across all sites except for one transect at Sucker Run Creek that showed 20 percent composition of tolerant taxa. Water temperature or other water quality conditions have not been identified in the area upstream of Lake Oroville, Lake Oroville, and in the Feather River below the Fish Barrier Dam at this time that would adversely affect macroinvertebrates (pers. comm., E. Brandstetter, MWH, 2004), though toxicity bioassays have identified impacts to test organisms at several monitored sites (DWR 2004). Cause of the toxicity has not been determined, nor have potential impacts to natural communities been determined. The community metrics of the basin water bodies examined indicate that the biotic community is only slightly disturbed, which suggests that the water quality is generally good.

6.2.1.5 Fisheries Management

Introduction of nonnative fish species into Lake Oroville and rivers of the Central Valley likely has impacted macroinvertebrate communities in rivers and reservoirs to an unknown extent. Several species of introduced fish, such as black crappie and red sunfish, rely on macroinvertebrates for food during significant portions of their life cycle. Many other piscivorous fish species (e.g., largemouth bass, spotted bass) utilize macroinvertebrates for their primary food source when they are juveniles. Information on the movement patterns of introduced species between tributaries and the reservoir is not known, but the proliferation of nonnative fish species in Lake Oroville likely has altered macroinvertebrate communities in tributaries to some extent. Downstream of the dam, information is not available to assess whether altered fish communities have impacted macroinvertebrate communities.

In general, the macroinvertebrate community of all the stations included many taxa that are important prey for fish species in the Project area, suggesting that the current macroinvertebrate community is structured adequately to support existing fisheries. Taxa important for fish include all the true flies, mayflies, caddisflies, and stoneflies. At some sites, however, stonefly taxa were absent or found in low densities, suggesting that habitat alteration of impacts from the associated fish community could be limiting.

Table 6.2.1-1 Matrix of directional impacts to macroinvertebrate resources from Project operation.

Current Impacts	Geographic Area(s)	Current Operations (Baseline)	General Impact Description	Directional Impact Assessment
Ramping in Feather River below Oroville Dam	Feather River below Oroville Dam	Flow changes under 2,500 cfs are to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.	Taxa richness and community diversity relatively uniform at most Feather River sites below the Fish Barrier Dam. Lower diversity and taxa richness at sites upstram of the Feather River Hatchery and above Honcut Creek.	Neutral
Minimum instream flow	Feather River downstream between Fish Barrier Dam and Thermalito Afterbay Outlet	The Oroville Facilities are operated to release a minimum of 600 cfs into the Feather River between the Fish Barrier Dam to the Thermalito Afterbay Outlet for fisheries purposes.	Minimum instream flows have resulted in altered temperature regimes in the Feather River and altered geomorphic processes. However, macroinvertebrate communities are generally similar in diversity and composition across most sites in the Feather River below Oroville Dam.	Neutral
Minimum instream flow	Feather River downstream of Thermalito Afterbay Outlet	The Oroville Facilities are operated to release a minimum of 600 cfs into the Feather River between the Fish Barrier Dam to the Thermalito Afterbay Outlet for fisheries purposes.	Dampening the Feather River hydrograph theoretically has liminted annual flushing flows that occurred naturally, thus allowing macroinvertebrates more favorable characteristics for colonization and expansion.	Positive
Managed flow downstream from Thermalito Afterbay Outlet	Feather River downstream of Thermalito Afterbay Outlet	Below Afterbay, 1,700 cfs from October through March, and 1,000 cfs from April through September during average water years.	Minimum instream flows have resulted in altered temperature regimes in the Feather River and altered geomorphic processes. However, macroinvertebrate communities are similar in diversity and composition across most sites in the Feather River below Fish Barrier Dam.	Neutral

Current Impacts	Geographic Area(s)	Current Operations (Baseline)	General Impact Description	Directional Impact Assessment
Armored substrate	Feather River between Fish Barrier Dam and Thermalito Afterbay Outlet	Substrates in some parts of this reach have become armored.	Areas of armored substrate provide limited habitat complexity and thus are associated with macroinvertebrate assemblages that are less diverse.	Negative
Temperature Regime Altered from Natural Conditions	Feather River below Oroville Dam	DWR is required to control water temperature at RM 61.6 (Robinson's Riffle) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average.	Lower water temperatures during summer for the benefit of anadromous fishes could delay macroinvertebrate reproduction and growth, and affect community composition. Although lower water temperatures likely would be within temperatures historically present in Feather River, altered temperature regimes could favor individual species or communities that are different from natural conditions.	Negative
Fish Stocking	Feather River below dam; OWA; Thermalito Complex	Salmonids are released from the Feather River Fish Hatchery into the Feather River.	Based on ecological principles, increased abundance of predators could be expected to result in lower macroinvertebrate densities, long-term shifts in macroinvertebrate size from selective predation, and shifts in community composition.	Negative

6.2.2 Phytoplankton and zooplankton

6.2.2.1 Habitat Availability

Maintenance of the reservoir and Project facilities such as the Thermalito Forebay, Thermalito Afterbay, and Fish Barrier Dam has resulted in increased habitat availability for plankton in Project waters from greatly increased surface area, including much greater area of lentic habitat. Based primarily on habitat availability, we concluded that current operation of the Project provides a net benefit to plankton resources.

6.2.2.2 Water Quality

The maximum depth of Lake Oroville is approximately 722 feet and thus likely falls into a category of reservoirs with plankton communities that are controlled by water quality (McQueen 1990). Seasonal temperature fluctuations likely affect the production potential of plankton. Higher water temperatures during spring and summer generally lead to increased plankton production but also typically lead to higher feeding rates by predators. Nutrient concentrations in Project waters also contribute to the production potential of plankton. Based on these ecological relationships, it is difficult to assess whether water temperature variations related to Project operations constitutes a significant detrimental or beneficial impact to plankton. At the time of this report, there are no known water quality constituents in Lake Oroville or other Project waters that exceed water quality criteria and would adversely affect plankton populations (pers. comm., E. Brandstetter, MWH, 2004). Therefore, impacts to plankton from water quality were considered neutral.

6.2.2.3 Fisheries Management

Lake Oroville contains many species of planktivorous fish and other fishes that may feed on zooplankton when other food resources are limited. Although the specific trophic dynamics in Lake Oroville have not be documented, the degree of impact from fishes to plankton populations in Lake Oroville and other Project waters is dependent on a suite of factors, including water quality, habitat characteristics, and the population dynamics of the most prevalent plankton predators (i.e., black crappie, wakasagi, and common carp). Species with planktivorous feeding strategies have the most potential to impact zooplankton and phytoplankton assemblages in Project waters. Nearly all fish species in reservoirs prey on zooplankton when they are fry. In Lake Oroville, black crappie, wakasagi, and common carp are the most prevalent species (classified as "frequently observed") that likely would impact zooplankton (DWR 2003). Threadfin shad and white crappie (classified as "infrequently observed") are two additional species that could impact zooplankton populations and community structure (DWR 2003). Threadfin shad and wakasagi also are specialized plankton predators. Overall, Project facilities have provided habitat for proliferation of non-target warmwater species, thus total predation on plankton has certainly increased compared to historical conditions. However, planktonic resources were limited in the previously existing riverine ecosystem (prior to completion of the Project),. Completion of the Project greatly expanded habitat for plankton as well as their predators, so while total predation on plankton has increased, the rate of predation on individual plankton prey and the effects of predation on plankton production have not necessarily changed. Despite these uncertainties, fish predation on plankton was considered to have a negative impact on the plankton. This conclusion should be interpreted with caution, however, because the effect of any Project-related impact of fish predation rate on plankton is trivial as compared to the benefit of the increased plankton habitat that the Project affords.

Table 6.2.2-2 Matrix of directional impacts to plankton resources from current Project operation.

Potential Impacts	Geographic Area(s)	Current Operations (Baseline)	General Impact Description	Directional Impact Assessment
Water temperature increase	Thermalito Afterbay, Lake Oroville	The Thermalito Afterbay is managed to provide water that meets temperature criteria and instream flow requirements in the Feather River. The Thermalito Afterbay also is operated to meet the needs of agricultural diverters. Lake Oroville is operated primarily for flood control, water supply, and power production.	Water temperature increases from project operations can result in an increased likelihood of plankton production, although plankton communities are seasonally variable and highly dynamic, affected by predator feeding rates, and are limited by nutrient availability. Specific shifts in community structure or species abundance are difficult to predict because of confounding environmental variables.	Neutral
Habitat Enhancement for Warmwater Species	Lake Oroville	DWR currently enhances habitat in Lake Oroville for warmwater species.	Increasing levels of fish predation likely alters plankton communities and decreases overall plankton abundance.	Negative

6.3 EVALUATION OF PROPOSED FUTURE PROJECT-RELATED IMPACTS

6.3.1 Macroinvertebrates

Potential impacts to macroinvertebrates from changes in Project operations were grouped into four general categories: (1) flow, (2) morphological changes to Feather River (e.g., gravel replacement, side-channel restoration), (3) water quality, and (4) fisheries management actions. A qualitative, directional analysis of impacts from these issues is provided in Table 6.3-1 and discussed in the following sections.

6.3.1.1 Flow-Related Potential Impacts

Ramping Rates

An August 1983 agreement between DWR and DFG entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife," sets criteria and objectives for flow and temperatures in the reach between the Fish Barrier Dam and Thermalito Afterbay Outlet and the reach of the Feather River between Thermalito Afterbay and Verona. One of the provisions in this agreement requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except in highly unusual circumstances (e.g., flood management). Several potential Project actions currently being examined by the Environmental Work Group would provide pulsed flows above existing levels for the benefit of fish migration in the Feather River below Oroville Dam.

In the reach of the Feather River between Oroville Dam and the Thermalito Afterbay Outlet, increases in flow would be designed primarily to more closely mimic the natural hydrograph in order to enhance emigration of juvenile salmonids. Flow increases downstream of the Thermalito Afterbay Outlet would be designed to improve migration conditions for adult sturgeon, shad, splittail, spring Chinook salmon, and steelhead. Flow increases in either reach would theoretically increase the amount of available habitat for macroinvertebrate colonization, therefore we assumed that increased flow would provide a benefit to macroinvertebrates. It is hypothesized that even if flows increase several hundred cubic feet per second in the reach between the Fish Barrier Dam and the Thermalito Afterbay Outlet, water velocities associated with higher flows would likely fall within historical ranges of what occurred in the Feather River and would not be detrimental to macroinvertebrate communities. At this time, the timing, duration, and magnitude of flow changes in these reaches, if any, have yet to be determined. It was assumed, however, that potential flow changes in both reaches would be in accordance with existing ramping guidelines and, therefore, any changes in ramping rates would be limited and impacts to macroinvertebrate populations would not differ substantially from those of baseline conditions. In summary, because increased flows would provide increased habitat for macroinvertebrates, and likely would not significantly affect migration and recolonization patterns, a "positive" impact was assigned if ramping occurs within established guidelines.

Changes in Flow

Initial results from a jointly conducted DWR and DFG instream flow study and subsequent PHABSIM analysis indicated that spawning habitat in the reach from the Fish Barrier Dam to the Thermalito Afterbay outlet would be maximized at about 1,000 cfs (Sommer *et al.* 2001). Results of the PHABSIM analysis conducted for the relicensing program indicates that spawning habitat peaks at flows between 800 to 825 cfs (DWR 2004a). The current agreement specifies that DWR release a minimum of 600 cfs downstream of the Fish Barrier Dam for fishery purposes. In the 15 miles of river between the Thermalito Afterbay Outlet and Honcut Creek, maximum suitable spawning habitat area was predicted to occur at approximately 3,250 cfs (Sommer *et al.* 2001). Current analysis for this reach indicates that spawning habitat peaks at flows between 1650 to 1750 cfs (DWR 2004a). Maximum predicted spawning habitat for the river's salmonid stocks in the upper reache would occur at flows slightly above current minimum flow requirements. In the lower reach, minimum instream releases are near optimal for spawning habitat.

Increasing flows to maximize salmonid spawning habitat would likely benefit benthic macroinvertebrate populations. Salmonid spawning habitat consists of gravel and cobble substrates in riffle or run areas of streams with rapid flow velocities. Such habitat is also utilized by many of the more desirable macroinvertebrate species. Therefore, increasing flows to maximize spawning habitat should lead to increased production and diversity of macroinvertebrates. In fact, any moderate flow increases, such as those that would be implemented for most potential Project actions, would likely benefit macroinvertebrates because gravel bars in and along the river channel would be increasingly inundated, providing increased substrate. The increased flows would need to be maintained for several months to allow for colonization of the substrates and significant growth and/or reproduction. Increased flows for salmonid spawning habitat would have to be maintained for several months to ensure successful spawning and egg incubation. Some existing habitat would lose value because their depths would be too deep, but the net result would likely be more suitable habitat. In summary, a "positive" impact was assigned to proposed flow increases in the Feather River below Oroville Dam because macroinvertebrate habitat would likely increase.

6.3.1.2 Morphological changes to Feather River

The reach of the Feather River between Oroville Dam and the Thermalito Afterbay Outlet contains relatively large areas of armored substrates. Substrate armoring in this segment has resulted from high-velocity flows transporting gravels downstream of this reach and a corresponding lack of gravel recruitment from upstream sources. Improving substrate diversity in this reach through gravel replenishment or other substrate enhancement techniques would provide a benefit to macroinvertebrate diversity in this reach. Recent data collection indicates that macroinvertebrate communities immediately downstream of the dam have slightly lower measures of diversity compared to other Feather River sites and contain a high abundance of Chironomids. Collectors and filterers generally dominate the macroinvertebrate assemblage at these sites. A rating of "strongly positive" was assigned because improved substrate quality and diversity in this reach has the potential to result in a more balanced invertebrate community.

Improving habitat quality in the reach between the Fish Barrier Dam and the Thermalito Afterbay Outlet through side-channel restoration would result in increased wetted area available for macroinvertebrates, thus providing a benefit to macroinvertebrates in the reach. A rating of "strongly positive" was assigned because macroinvertebrate habitat was predicted to improve.

6.3.1.3 Water Quality

Operational changes to lower water temperature in the Feather River during summer below Oroville Dam are currently being considered by the Environmental Work Group. Operational changes to seasonally lower water temperature for the benefit of anadromous fishes in the Feather River would be achieved by drawing water from deeper reservoir depths or by altering water delivery patterns at the Thermalito Afterbay Outlet. Lowering water temperatures during summer could delay macroinvertebrate reproduction and growth, diminish food supplies (via periphyton growth), and potentially could alter community composition and densities, which could then affect fisheries populations. Further, since lower water temperatures were historically present in the winter but were warmer in the summer, cooling the river during summer likely favors species that historically were not present in the Feather River under a natural flow regime. Because of the potential to adversely affect macroinvertebrate reproduction and growth, we assigned a rating of "negative" to project actions designed to improve water quality conditions for migrating fishes. Potential Project actions are not likely to affect other water quality parameters in the Feather River and, therefore, were not evaluated.

6.3.1.4 Fisheries Management

At the time of this report, several fisheries management actions are being considered to enhance fisheries resources within Project waters. Most of these measures are related to fish stocking efforts in Lake Oroville, Thermalito Afterbay, and Oroville Wildlife Area ponds. Fish stocking efforts in the Thermalito Afterbay and OWA would be designed to enhance the potential for warm water fisheries. Fish stocking in Lake Oroville is designed to increase salmon production for recreational purposes. An additional Resource Action that is being considered involves transporting live salmon to tributaries upstream of Lake Oroville during spawning.

Evaluating changes to macroinvertebrate densities and community composition from future changes in fish management is difficult because limited site-specific data is available to characterize ecological interactions between fish and invertebrate species. Further, changes in community metrics (e.g., functional feeding group classifications) that are used to determine whether a macroinvertebrate community is "better" or "worse" as a result of potential Project actions can often be masked by confounding ecological processes. In principle, more fish in the Feather River below Oroville Dam, Lake Oroville, Thermalito Complex, or the OWA might be expected to translate into lower macroinvertebrate densities, long-term shifts in macroinvertebrate size from selective predation, or shifts in community composition in these locations, as described in section 6.1.1.2, "Effects of Fish on Macroinvertebrate Communities." Greater fish abundance in the Feather River also could result in better utilization of existing macroinvertebrate resources because more fish theoretically could reduce the number of organisms that drift out of the region to unsuitable habitats. However, the authors' are uncertain whether changes to the existing community would be beneficial or detrimental, or even occur in conjunction with fish stocking. Therefore, we cautiously characterize the potential effect of fish stocking in target areas below Oroville Dam as a negative impact based solely on the ecological principles described in Section 6.1.1.2, "Effects of Fish on Macroinvertebrate Communities."

A positive impact to macroinvertebrates communities is predicted for potential Project actions to transport adult salmon to upper tributaries for spawning. The marine-derived nutrients contained in the bodies and reproductive and metabolic products of the salmon would be released in the streams after the salmon spawned and died, which may lead to increased production of benthic macroinvertebrates. Several studies have documented a positive effect of salmon spawning migrations on stream invertebrates (see technical study SP-F8). Artificially providing nutrients to the streams may have a similar effect, especially if the streams are indeed "nutrient –limited" or "nutrient-starved". The authors acknowledge, however, that adding salmon to a stream where nutrients are not limiting could have adverse ecological impacts, potentially even altering community structure.

The greatest benefit to macroinvertebrates would occur in a situation where fish were restored to an area that was nutrient-limited or nutrient-starved. Although data indicates that streams upstream of Lake Oroville contain low levels of nutrients, streams above the lake currently are not categorized as nutrient starved. The data also indicate that healthy populations of aquatic macroinvertebrates currently exist in the upstream tributaries. Based on literature that suggests inputs of marine-derived nutrients often provide a positive benefit, we cautiously conclude that transporting salmon to upper tributaries for spawning would provide a "positive" impact to macroinvertebrates.

Table 6.3.1-1 Matrix of directional impacts to macroinvertebrate resources from potential changes in Project operation or proposed actions.

Potential Impacts	Geographic Area(s)	Current Operations (Baseline)	General Description of Proposed Actions	General Impact Description	Directional Impact Assessment
Alter ramping rates in Feather River below Oroville Dam	Feather River downstream Oroville Dam	Flow changes under 2,500 cfs are to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.	Provide pulsed flows above existing levels for benefit of fish migration. Target flow magnitudes and timing of flow pulses have yet to be determined.	No net change from baseline impacts expected as pulsed flows presumably would be increased according to current ramping requirements	Neutral
Change flow magnitude in Feather River below Oroville Dam	Feather River downstream of Thermalito Afterbay Outlet	The Oroville Facilities are operated to release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes.	Incrementally increase flows in the reach between Fish Barrier Dam to Thermalito Afterbay Outlet from relatively low flows to relatively high flows for the benefit of Chinook salmon.	Increasing flow would inundate additional spawning gravels, aid in fish spawning and incubation, and create more macroinvertebrate habitat.	Positive
Change flow magnitude in Feather River below Oroville Dam	Feather River downstream of Thermalito Afterbay Outlet	Below Afterbay, 1,700 cfs from October through March, and 1,000 cfs from April through September during average water years.	Provide increased flow from the Thermalito Afterbay Outlet or the Thermalito Diversion Dam to facilitate fish migration.	Increasing flow could alter migration and colonization patterns, especially if extreme scouring flows were utilized.	Positive
Gravel Replenishment	Feather River between Oroville Dam and Thermalito Afterbay Outlet	Substrates in some parts of the reach between Fish Barrier Dam and Thermalito Afterbay Outlet have become armored.	Spawning gravel quality would be improved in target sections of the reach between Fish Barrier Dam to Thermalito Afterbay Outlet for the benefit of spawning salmon.	Improving spawning gravel quality in target areas of the reach between Fish Barrier Dam and Thermalito Afterbay Outlet would result in areas with large cobble substrates that previously were armored. Depending on the number and size of target areas, improved substrate quality would provide a benefit to macroinvertebrate diversity and community structure (via improved habitat for recolonization).	Strongly Positive
Side-channel Restoration	Feather River downstream of Thermalito Afterbay Outlet	Existing side channels have been affected by levees and project operation.	Target side channels would be created or enhanced to provide habitat for spawning salmonids. Water likely would be diverted from the Feather River and side channels would have approximately 10-30 cfs of flow.	Increasing the quantity and quality of side channel habitat in the lower Feather River also provide a habitat benefit for macroinvertebrates. Depending on the number and size of target side-channel areas, increased habitat would provide a benefit to macroinvertebrate diversity and abundance in this reach.	Strongly Positive

Potential Impacts	Geographic Area(s)	Current Operations (Baseline)	General Description of Proposed Actions	General Impact Description	Directional Impact Assessment
Temperature	Feather River below Oroville Dam	DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average.	Increased amounts of water would be released into the lower Feather River to decrease water temperatures for the benefit of salmon and other fish species.	Lower water temperatures in the lower Feather River could affect macroinvertebrate reproduction, growth, and community composition; however, lower water temperatures likely would be within temperatures historically present in Feather River.	Negative
Fish Stocking	Feather River below dam; OWA; Thermalito Complex	Salmonids are released from the Feather River Fish Hatchery into the Feather River.	Warmwater species, such as bass, would be stocked into target areas within the Thermalito Complex and OWA, and salmonids would be released in higher numbers into the Feather River.	Based on ecological principles, increased abundance of predators could be expected to result in lower macroinvertebrate densities, long-term shifts in macroinvertebrate size from selective predation, and shifts in community composition.	Negative
Upstream fish transport	Above Lake Oroville	Oroville Dam prevents upstream fish passage into tributaries where salmon historically spawned.	Transport salmon that have returned to the Feather River below Oroville Dam to upstream tributaries.	Transporting live salmon to tributaries of Lake Oroville during spawning could result in ecological benefits (e.g., marine-derived nutrients) and thus benefits to macroinvertebrate communities would be realized.	Positive

6.3.2 Plankton

6.3.2.1 Increased Habitat Availability

Potential future Project actions include measures to improve recreational opportunities in Lake Oroville and warmwater fish nesting and rearing habitat in Thermalito Afterbay by maintaining relatively high water levels in the summer and spring, respectively. Increasing water levels would provide increased habitat volume for phytoplankton and zooplankton communities, which would likely result in an increased total production of plankton. Increasing plankton production would, in principle, lead to greater fish production. Therefore, this is considered a positive project effect.

Measures proposed to increase side-channel habitat in the lower Feather River would increase the availability of shallow pool habitat. Side-channel pool habitat is excellent for production of plankton. Zooplankton in side-channel pools is an important food resource for rearing salmonids and other fish, as well as for macroinvertebrates on which the fish prey as they grow larger. Therefore, this is considered a strongly positive project effect.

6.3.2.2 Water Quality

Several potential future Project actions would potentially affect plankton as a result of effects on water quality. These include actions to warm water temperatures in the Thermalito Afterbay, measures to transport anadromous salmonids to Feather River tributaries upstream of Lake Oroville, measures to artificially augment nutrients in the upstream tributaries, and actions to chemically control weeds in OWA ponds.

Warming of the Thermalito Afterbay would likely cause changes in plankton species composition, and possibly abundance. Although the Thermalito Afterbay is low in nutrients, increased temperatures could result in higher algal biomass and enhanced nutrient cycling. Blue-green algae populations in particular could increase due to warming because this type of algae can obtain nitrogen from the atmosphere. Phytoplankton communities dominated by blue-green algae, however, are not desirable since these algae are not readily consumed by planktivorous species and their decomposition often leads to unsightly scums and odors. In addition, higher temperatures could result in increased methylation of mercury and bioaccumulation in the food web.A rating of "negative" was assigned because higher water temperatures would be expected to slightly increase plankton production, but possible increases in blue-green algal production and mercury methylation would have negative effects.

Transporting adult salmonids to the upstream tributaries or artificially increasing nutrients in these streams could result in increased nutrient loading to Lake Oroville. The increased nutrient loading would potentially have an effect on plankton production and community structure, but the increases would likely not be substantial. Therefore, the effect of increasing nutrient loading on plankton production would likely be positive, but minor.

Chemical treatment with glycophosphate herbicide (e.g., Rodeo) of the OWA ponds to control water primrose could result in some increase of phytoplankton biomass. More plankton could occur because of increased open water habitat, though predation may also increase as fish densities rise in response to more quality habitat. We cautiously concluded that as water primrose abundance decreased in OWA ponds, a net increase in plankton abundance would occur, which would be considered a positive result.

6.3.2.3 Fisheries Management

Potential future Project actions that involve fish stocking programs for Lake Oroville, the Thermalito Afterbay and OWA ponds could affect zooplankton production and community structure. Most fish stocking would probably be implemented using larger game fish, most of which prey on macroinvertebrates and smaller fish rather than zooplankton. However, if the stocked fish significantly reduced the abundance of macroinvertebrates and small fish that feed on zooplankton, reduced predation pressure on the zooplankton could lead to changes in zooplankton production and community structure. Changes in the zooplankton could lead to changes in phytoplankton productions and community structure. Effects of changing trophic interactions in lentic environments are complex and their consequences are difficult to predict. Given this uncertainty, and the likelihood that effects of fish management on plankton, if any, would be minor, a rating of "neutral" was assigned to fisheries management.

Table 6.3.2-1 Matrix of directional impacts to plankton resources from potential changes in Project operation or proposed actions.

Potential Impacts	Geographic Area(s)	Current Operations (Baseline)	General Description of Proposed Actions	General Impact Description	Directional Impact Assessment
Side Channel Restoration	Feather River between Oroville Dam and Thermalito Afterbay Outlet	Existing side channels have been affected by levees and project operation.	Target side channels would be created or enhanced to provide habitat for spawning salmonids. Water likely would be diverted from the Feather River and side channels would have approximately 10-30 cfs of flow.	Increasing side channel habitat would increase availability of side pool habitat, and thus production, for plankton.	Strongly Positive
Increase water level in Thermalito Afterbay	Thermalito Afterbay	The Thermalito Afterbay is managed to provide water that meets temperature criteria and instream flow requirements in the Feather River. The Thermalito Afterbay also is operated to meet the needs of agricultural diverters.	Increase water level in Thermalito Afterbay for benefit of waterfowl and warmwater fish production.	Increased volume of water would be available for plankton production.	Positive
Water temperature increases	Thermalito Afterbay	The Thermalito Afterbay is managed to provide water that meets temperature criteria and instream flow requirements in the Feather River. The Thermalito Afterbay also is operated to meet the needs of agricultural diverters.	Water temperatures would be increased in the Thermalito Afterbay for the benefit of agricultural users.	Increased water temperature could lead to increased plankton production, but if nitrogen is limited, warmer temperatures would likely favor blue-green algae, which are undesirable.	Negative
Nutrient Increases	Lake Oroville tributaries	Based on studies conducted in tributaries upstream of Lake Oroville, nutrient concentrations (i.e., Nitrogen, Phosphorus, Organic Carbon) are below nuisance levels.	Adult salmonids would be transported to upstream tributaries for spawning.	Increasing nutrients in tributaries would slightly increase nutrient concentrations in these areas.	Positive
Chemical treatment of ponds	OWA	OWA ponds are not managed to curtail proliferation of exotic species or plants that can be detrimental to fish and waterfowl production (e.g., water primrose).	Target OWA ponds would be chemically treated to eliminate undesired aquatic plant species.	Increasing levels of fish predation via chemical treatment of OWA ponds could alter plankton communities and increase overall plankton abundance.	Positive
Fish Stocking	OWA, Thermalito Afterbay, Lake Oroville	DWR currently enhances habitat in Lake Oroville for warmwater species. DWR does not manage Thermalito Afterbay or OWA for trophy warmwater fishery.	DWR would mange Thermalito Afterbay and OWA for trophy fishery. Lake Oroville fish stocking efforts would continue, and salmon would be stocked in Lake Oroville tributaries.	Increasing levels of fish predation via stocking could decrease overall plankton abundance, but it could also reduce abundance of small fish and macroinvertebrates that prey on plankton, which could result in increased plankton abundance.	Neutral

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APPENDIX A—MACROINVERTEBRATE RAW DATA

Table A-1. List of macroinvertebrate sampling stations by name, habitat area, sample type, and lead organization.

Station Name	Habitat Area	Sample Type/ Organization
Fall River Upstream Feather Falls	Area Upstream of Lake Oroville Inundation Zone	Riffle--DWR
Feather River Middle Fork Near Merrimac	Area Upstream of Lake Oroville Inundation Zone	Riffle--DWR
Feather River North Fork Upstream Poe PH	Area Upstream of Lake Oroville Inundation Zone	Riffle--DWR
West Branch Feather River Near Paradise	Area Upstream of Lake Oroville Inundation Zone	Riffle--DWR
Feather River South Fork Above Ponderosa Reservoir	Area Upstream of Lake Oroville Inundation Zone	Riffle--DWR
Sucker Run Creek Near Forbestown	Area Upstream of Lake Oroville Inundation Zone	Riffle--DWR
Concow Creek Above Jordan Hill Rd	Area Upstream of Lake Oroville Inundation Zone	Riffle--DWR
Feather River SF Inundation Zone	Lake Oroville Inundation Zone	Riffle--DWR
Feather River Upstream Thermalito Afterbay Outlet	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--DWR
Feather River at Robinson Riffle	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--DWR
Feather River Downstream Hatchery	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--DWR
Feather River Downstream Highway 162	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--DWR
Feather River Upstream Hatchery	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--DWR
Glen Creek Upstream of Glen Pond	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--DWR
Feather River Near Fish Barrrier Dam	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Submerged (Ponar)
Hatchery Ditch	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU

Station Name	Habitat Area	Sample Type/ Organization
Hatchery Riffle	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU
Robinson Main	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU
Robinson Side	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU
Steep Main	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU
Steep Side	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU
Eye Main	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU
Eye Side	Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	Riffle--CSU
Feather River downstream to Afterbay Outlet	Lower Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek	Riffle--DWR
Feather River Near Mile Long Pond	Lower Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek	Riffle--DWR
Feather River Downstream SCOR Outlet	Lower Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek	Riffle--DWR
Feather River Above Honcut Creek	Lower Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek	Riffle--DWR
Feather River Downstream Project Boundary	Lower Feather River downstream of Honcut Creek	Riffle--DWR
Feather River Above Archer Avenue	Lower Feather River downstream of Honcut Creek	Riffle--DWR
Feather River above Shanghai Bend	Lower Feather River downstream of Honcut Creek	Riffle--DWR
Feather River above Yuba River Confluence	Lower Feather River downstream of Honcut Creek	Submerged (Ponar)
Feather River near Verona	Lower Feather River downstream of Honcut Creek	Submerged (Ponar)
Vance Avenue	Lower Feather River downstream of Honcut Creek	Riffle--CSU
Hour	Lower Feather River downstream of Honcut Creek	Riffle--CSU

Station Name	Habitat Area	Sample Type/ Organization
MacFarland	Lower Feather River downstream of Honcut Creek	Riffle--CSU
Shallow	Lower Feather River downstream of Honcut Creek	Riffle--CSU
Mile Long Pond	Oroville Wildlife Area	Submerged (Ponar)
Sacramento River above Feather River Confluence	Sacramento and Yuba Rivers	Submerged (Ponar)
Yuba River	Sacramento and Yuba Rivers	Submerged (Ponar)

Source: (pers.comm., J. Boles, DWR 2003/2004)

Table A-2. Summary metrics for aquatic macroinvertebrates collected in riffles by DWR. Three individual samples were collected across each transect (T) and combined, resulting in a combined sample at each transect.

	West Branch Feather River Near Paradise				North Fork Feather River Upstream Poe PH				South Fork Feather River above Ponderosa Reservoir			
	T1	T2	T3	Total	T1	T2	T3	Total	T1	T2	T3	Total
Total Organisms	291	302	313	906	296	291	302	889	303	289	290	882
Cumulative Taxa	30	29	32	49	25	21	15	38	25	26	33	41
EPT Taxa	16	14	16	29	10	10	9	16	7	6	9	12
Ephemeroptera Taxa	4	5	4	6	4	2	2	4	3	2	3	4
Plecoptera Taxa	6	3	4	10	0	0	0	0	0	0	0	0
Trichoptera Taxa	6	6	8	13	6	8	7	12	4	4	6	8
EPT Index	63	51	44	53	22	54	40	39	15	19	20	18
Sensitive EPT Index	11	5	7	8	1	0	0	0	0	0	0	0
Shannon Diversity	2.7	2.4	2.6	2.7	1.8	2.3	1.7	2.5	1.7	2.0	2.3	2.1
Tolerance Value	4.4	5.0	4.7	4.7	5.6	5.2	5.4	5.4	5.8	5.5	5.6	5.6
Percent Intolerant Organisms	6	4	7	6	1	0	0	0	0	4	1	2
Percent Tolerant Organisms	1	5	2	3	2	1	1	1	0	3	2	2
Percent Hydropsychidae	16	9	7	10	0	15	13	9	2	10	10	7
Percent Baetidae	17	19	10	15	1	22	15	13	8	6	6	7
Percent Chironomidae	18	31	28	26	55	21	7	28	62	52	49	54
Percent Dominant Taxon	18	31	28	26	55	21	49	21	62	52	49	54
Percent Collectors	44	59	54	52	74	53	25	50	71	69	64	68
Percent Filterers	28	13	10	16	0	36	71	36	10	20	15	15
Percent Grazers	1	22	27	23	1	10	3	10	1	4	13	9
Percent Predators	7	6	9	7	7	1	0	2	8	7	8	8
Percent Shredders	1	0	1	1	0	0	0	0	0	0	0	0

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected in riffles by DWR. Three individual samples were collected across each transect (T) and combined, resulting in a combined sample at each transect.

	Middle Fork Feather River Near Merrimac				Fall River upstream Feather Falls				Sucker Run Creek near Forbestown			
	T1	T2	T3	Total	T1	T2	T3	Total	T1	T2	T3	Total
Total Organisms	294	294	298	886	271	294	319	884	287	298	292	877
Cumulative Taxa	31	33	27	47	29	30	29	47	32	29	29	45
EPT Taxa	18	20	16	29	15	14	14	23	9	13	12	16
Ephemeroptera Taxa	6	8	6	9	7	7	7	9	6	7	5	7
Plecoptera Taxa	4	4	2	6	2	3	3	5	0	3	3	4
Trichoptera Taxa	8	8	8	14	6	4	4	9	3	3	4	5
EPT Index	62	69	73	68	51	34	42	42	24	20	31	25
Sensitive EPT Index	3	8	2	5	15	14	17	15	7	12	9	9
Shannon Diversity	2.5	2.8	2.2	2.7	2.6	2.6	2.6	2.7	2.7	2.2	2.5	2.6
Tolerance Value	4.7	4.2	4.8	4.6	3.9	4.1	3.8	3.9	5.2	4.4	5.1	4.9
Percent Intolerant Organisms	4	7	1	4	17	16	20	18	6	10	8	8
Percent Tolerant Organisms	2	2	0	2	0	0	0	0	20	0	8	9
Percent Hydropsychidae	16	15	32	21	1	0	0	0	0	0	0	0
Percent Baetidae	31	24	26	27	8	2	1	4	2	2	5	3
Percent Chironomidae	17	4	6	9	12	23	17	18	18	28	30	25
Percent Dominant Taxon	30	21	26	26	24	23	20	22	18	32	30	25
Percent Collectors	63	51	37	50	38	40	34	37	46	36	49	44
Percent Filterers	20	29	52	34	3	0	0	1	0	0	1	1
Percent Grazers	1	13	7	10	1	41	43	44	1	51	34	42
Percent Predators	6	3	3	4	6	10	16	11	9	7	14	10
Percent Shredders	1	3	0	1	3	8	8	7	3	6	2	4

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected in riffles by DWR. Three individual samples were collected across each transect (T) and combined, resulting in a combined sample at each transect.

	Concow Creek at Jordan Hill Road				South Fork Feather River Innundation Zone				Feather River Near Mile Long Pond			
	T1	T2	T3	Total	T1	T2	T3	Total	T1	T2	T3	Total
Total Organisms	114	310	309	733	303	301	74	678	301	295	303	899
Cumulative Taxa	21	20	20	31	12	16	11	19	21	19	14	28
EPT Taxa	10	7	10	14	3	4	4	4	9	9	7	10
Ephemeroptera Taxa	3	2	4	5	1	2	2	2	4	5	4	5
Plecoptera Taxa	3	2	2	4	0	0	0	0	0	0	0	0
Trichoptera Taxa	4	3	4	5	2	2	2	2	5	4	3	5
EPT Index	25	6	9	10	43	54	32	47	57	78	81	72
Sensitive EPT Index	4	2	1	2	0	0	0	0	5	4	2	4
Shannon Diversity	2.0	1.4	1.4	2.0	1.5	1.6	1.9	1.8	2.3	2.1	1.9	2.3
Tolerance Value	4.4	6.0	5.8	5.7	4.0	5.0	5.1	4.6	5.1	4.4	4.3	4.6
Percent Intolerant Organisms	4	2	1	2	0	0	0	0	6	4	2	4
Percent Tolerant Organisms	5	13	1	7	0	1	1	1	4	0	0	2
Percent Hydropsychidae	3	0	1	1	38	41	22	38	7	29	20	19
Percent Baetidae	11	0	6	4	5	10	4	7	12	32	47	30
Percent Chironomidae	0	65	31	41	31	32	16	30	23	14	5	14
Percent Dominant Taxon	49	65	52	41	38	41	30	38	22	32	43	29
Percent Collectors	24	81	40	55	43	46	26	42	53	54	63	57
Percent Filterers	3	2	53	24	39	45	51	43	8	32	21	21
Percent Grazers	1	7	3	14	1	4	4	2	1	12	8	19
Percent Predators	18	8	4	8	18	4	19	12	4	2	8	5
Percent Shredders	1	1	0	1	0	1	0	0	0	0	0	0

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected in riffles by DWR. Three individual samples were collected across each transect (T) and combined, resulting in a combined sample at each transect.

	Feather River Upstream Hatchery				Feather River Downstream Hatchery				Feather River Downstream Highway 162			
	T1	T2	T3	Total	T1	T2	T3	Total	T1	T2	T3	Total
Total Organisms	287	280	303	870	304	306	289	899	274	306	302	882
Cumulative Taxa	14	11	17	20	20	18	13	26	15	19	22	29
EPT Taxa	7	5	7	8	6	6	5	7	6	5	9	9
Ephemeroptera Taxa	3	3	4	4	4	3	4	4	3	3	6	6
Plecoptera Taxa	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera Taxa	4	2	3	4	2	3	1	3	3	2	3	3
EPT Index	3	3	9	5	18	26	31	25	13	35	28	26
Sensitive EPT Index	1	0	0	1	1	0	0	1	1	0	2	1
Shannon Diversity	0.6	0.5	1.3	0.9	1.4	1.5	1.5	1.6	1.0	1.8	1.7	1.6
Tolerance Value	6.1	6.1	5.9	6.0	5.7	5.6	5.5	5.6	5.8	5.4	5.5	5.6
Percent Intolerant Organisms	0	0	0	0	0	0	0	0	0	0	1	1
Percent Tolerant Organisms	6	5	5	5	5	3	0	3	1	3	2	2
Percent Hydropsychidae	0	1	3	1	1	7	11	6	3	7	8	6
Percent Baetidae	0	1	3	1	13	19	15	16	2	25	15	15
Percent Chironomidae	87	89	72	83	67	60	59	62	79	49	57	61
Percent Dominant Taxon	87	89	72	83	67	60	59	62	79	49	57	61
Percent Collectors	95	96	80	90	89	83	81	84	83	80	79	81
Percent Filterers	1	1	16	6	4	10	16	10	4	13	13	10
Percent Grazers	1	0	1	0	1	1	0	1	1	2	4	5
Percent Predators	3	3	2	3	5	6	3	5	4	6	4	5
Percent Shredders	0	0	0	0	0	0	0	0	0	0	0	0

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected in riffles by DWR. Three individual samples were collected across each transect (T) and combined, resulting in a combined sample at each transect.

	Feather River at Robinson Riffle				Feather River upstream Afterbay Outlet				Glen Creek upstream Glen Pond			
	T1	T2	T3	Total	T1	T2	T3	Total	T1	T2	T3	Total
Total Organisms	278	304	306	888	294	307	306	907	306	304	291	901
Cumulative Taxa	20	18	18	27	21	21	15	31	24	25	19	32
EPT Taxa	6	6	7	8	5	7	7	10	8	9	8	11
Ephemeroptera Taxa	4	4	4	4	3	4	4	5	4	3	3	4
Plecoptera Taxa	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera Taxa	2	2	3	4	2	3	3	5	4	6	5	7
EPT Index	59	76	72	69	52	43	71	55	41	34	51	42
Sensitive EPT Index	6	9	6	7	0	0	0	0	24	20	43	29
Shannon Diversity	2.3	2.1	2.1	2.3	2.3	2.2	1.6	2.2	2.4	2.3	2.0	2.4
Tolerance Value	4.9	4.5	4.7	4.7	5.4	5.5	4.8	5.2	4.7	4.9	3.9	4.5
Percent Intolerant Organisms	6	9	6	7	0	0	0	0	25	21	44	30
Percent Tolerant Organisms	6	5	3	5	14	9	2	8	8	4	8	7
Percent Hydropsychidae	5	28	25	20	10	14	49	25	2	4	2	3
Percent Baetidae	47	38	40	42	38	27	18	28	0	7	3	4
Percent Chironomidae	9	9	12	10	15	18	12	15	30	30	13	25
Percent Dominant Taxon	29	28	25	24	23	23	49	24	30	30	42	27
Percent Collectors	68	60	59	62	65	49	33	49	46	41	18	35
Percent Filterers	15	34	32	27	21	37	62	40	5	12	8	8
Percent Grazers	1	4	4	5	1	10	5	8	1	34	63	46
Percent Predators	11	2	5	6	4	3	1	3	6	13	10	10
Percent Shredders	0	0	0	0	0	0	0	0	0	0	1	0

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected in riffles by DWR. Three individual samples were collected across each transect (T) and combined, resulting in a combined sample at each transect.

	Feather River downstream Afterbay Outlet				Feather River above Honcut Creek				Feather River downstream SCOR Outfall			
	T1	T2	T3	Total	T1	T2	T3	Total	T1	T2	T3	Total
Total Organisms	301	308	290	899	299	297	294	890	311	285	302	898
Cumulative Taxa	21	15	16	26	12	13	10	16	17	14	16	24
EPT Taxa	12	10	8	13	7	6	6	7	9	8	7	13
Ephemeroptera Taxa	5	4	4	5	4	3	4	4	4	3	3	5
Plecoptera Taxa	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera Taxa	7	6	4	8	3	3	2	3	5	5	4	8
EPT Index	68	81	79	76	83	86	84	84	64	78	61	67
Sensitive EPT Index	2	1	1	1	0	0	0	0	0	0	0	0
Shannon Diversity	2.2	1.7	1.9	2.0	1.7	1.6	1.4	1.6	1.8	1.8	1.9	1.9
Tolerance Value	4.6	4.5	4.6	4.6	4.4	4.4	4.5	4.4	4.8	4.6	4.8	4.7
Percent Intolerant Organisms	2	1	1	1	0	0	0	0	0	0	0	0
Percent Tolerant Organisms	1	0	0	0	0	1	1	1	2	1	1	1
Percent Hydropsychidae	42	53	51	48	46	42	54	47	37	55	43	45
Percent Baetidae	13	20	18	17	32	38	24	31	18	14	9	14
Percent Chironomidae	8	11	10	10	6	7	11	8	24	11	19	18
Percent Dominant Taxon	36	49	44	43	45	40	54	47	37	49	40	42
Percent Collectors	27	36	36	33	41	48	38	42	45	29	30	35
Percent Filterers	44	55	53	51	49	44	57	50	39	56	43	46
Percent Grazers	1	9	10	15	1	6	5	6	1	14	23	17
Percent Predators	3	0	1	2	2	1	0	1	2	1	4	2
Percent Shredders	0	0	0	0	0	0	0	0	0	0	0	0

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected in riffles by DWR. Three individual samples were collected across each transect (T) and combined, resulting in a combined sample at each transect.

	Feather River upstream Archer				Feather River at Shanghai Bend Falls				Feather River below Project			
	T1	T2	T3	Total	T1	T2	T3	Total	T1	T2	T3	Total
Total Organisms	306	307	304	917	293	297	309	899	299	315	307	921
Cumulative Taxa	14	16	18	24	17	16	15	22	16	20	15	22
EPT Taxa	8	9	9	13	7	7	8	10	9	14	10	15
Ephemeroptera Taxa	3	6	5	7	4	4	5	5	4	4	4	4
Plecoptera Taxa	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera Taxa	5	3	4	6	3	3	3	5	5	10	6	11
EPT Index	73	62	69	68	65	93	59	72	75	90	87	84
Sensitive EPT Index	2	1	4	2	2	4	3	3	1	2	1	2
Shannon Diversity	1.2	1.7	1.5	1.6	2.1	1.5	2.1	2.1	1.9	1.8	1.8	1.9
Tolerance Value	4.6	4.9	4.6	4.7	4.9	4.2	4.9	4.7	4.7	4.3	4.4	4.5
Percent Intolerant Organisms	2	1	4	2	2	4	3	3	1	2	1	1
Percent Tolerant Organisms	3	1	5	3	3	1	0	1	0	1	0	0
Percent Hydropsychidae	1	3	6	3	12	35	9	19	7	34	36	26
Percent Baetidae	66	49	57	57	42	53	31	42	50	48	45	47
Percent Chironomidae	20	32	20	24	22	3	30	18	10	4	8	8
Percent Dominant Taxon	66	40	56	54	26	37	30	28	46	38	34	40
Percent Collectors	92	86	85	88	75	61	68	68	66	58	57	60
Percent Filterers	2	4	7	4	13	35	12	20	12	38	40	30
Percent Grazers	1	7	8	6	1	1	16	7	1	3	2	8
Percent Predators	1	3	1	2	8	2	5	5	2	1	0	1
Percent Shredders	0	0	0	0	0	0	0	0	0	0	0	0

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected in submerged samples (i.e., ponar) by DWR.

	Sacramento River above Feather River Confluence	Feather River above Yuba River	Yuba River	Feather River Near Verona	Mile Long Pond	Feather River Near Fish Barrier Dam
	Submerged Collection	Submerged Collection	Submerged Collection	Submerged Collection	Submerged Collection	Submerged Collection
Total Organisms	42	61	373	38	64	136
Cumulative Taxa	3	3	15	3	6	10
EPT Taxa	0	1	3	0	1	1
Ephemeroptera Taxa	0	1	1	0	1	0
Plecoptera Taxa	0	0	0	0	0	0
Trichoptera Taxa	0	0	2	0	0	1
EPT Index	0	2	30	0	2	1
Sensitive EPT Index	0	2	1	0	0	1
Shannon Diversity	0.7	0.5	1.8	0.8	1.0	1.3
Tolerance Value	5.9	5.9	5.8	6.0	5.8	6.4
Percent Intolerant Organisms	0	2	0	0	0	0
Percent Tolerant Organisms	0	0	20	0	3	43
Percent Hydropsychidae	0	0	0	0	0	1
Percent Baetidae	0	0	0	0	0	0
Percent Chironomidae	79	13	19	37	61	1
Percent Dominant Taxon	79	85	29	58	61	54
Percent Collectors	86	15	75	37	94	78
Percent Filterers	14	85	0	58	0	17
Percent Grazers	0	0	1	5	0	0
Percent Predators	0	0	24	0	6	5
Percent Shredders	0	0	0	0	0	0

Table A-3. Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye Main, Steep Main, Robinson Main, and Hatchery Riffle page 1)

Taxonomic Group			TV	FFG	Eye Main (RM 60.1)			Steep Main (RM 61.0)			Robinson Main (RM 61.9)			Hatchery Riffle (RM 66.6)		
					Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Acari																
	Anasitsilidae					-	36	-	-	-	-	-	-	-	-	-
	Arreneuridae				-	-	-	-	-	-	-	-	36	-	-	-
	Hygrobatidae				-	208	72	-	-	19	-	-	72	19	72	67
	Lebertidae				28	64	1,092	-	108	664	56	175	180	523	756	402
	Oribatid				10,708	25,795	11,340	1,248	20,808	2,395	5,877	23,483	3,564	6,783	13,752	3,429
	Pionidae				-	-	24	-	-	-	-	-	-	-	-	-
	Sperchontidae				24	347	240	36	720	488	96	286	252	263	1,332	222
	Torrenticolidae				-	147	756	-	144	464	-	-	-	-	72	395
(juvenile)	Unknown				-	72	-	-	72	-	-	-	-	9	-	16
	Unknown				-	-	-	-	-	-	-	-	-	-	36	-
Order Collembola																
	Hypogastruidae				56	-	-	-	-	-	-	-	-	-	-	-
Order Coleoptera																
(larva)	Unknown				-	-	24	-	-	-	-	-	-	-	-	-
(adult)	Unknown				-	-	36	-	-	-	-	-	-	-	-	-
(larva)	Elmidae	*Optioservus*	4	g	-	-	-	-	36	-	-	-	-	-	-	-
(larva)	Elmidae	*Ordobrevia*	4	g	-	-	-	-	72	-	-	-	-	-	-	-
(larva)	Elmidae	*Zaitzevia*	4	c	-	-	-	36	-	-	-	-	-	-	-	-
(larva)	Elmidae				-	-	36	32	-	-	-	-	-	-	-	-
Order Diptera																
(larva)	Ceratopogonidae				-	-	24	-	21	-	-	-	-	-	-	16
(pupa)	Ceratopogonidae				-	-	72	-	36	-	-	-	-	-	-	-
(larva)	Chironomidae				5,444	8,565	18,972	3,892	17,100	2,747	2,581	10,421	1,692	19,179	30,924	1,475
(pupa)	Chironomidae				112	264	840	172	720	157	315	355	432	869	1,404	331
(larva)	Empididae	*Chelifera*	6	p	-	-	192	-	-	19	-	-	36	-	-	-
(larva)	Empididae				28	-	36	32	-	-	-	-	-	19	-	16
(larva)	Simulidae				16,320	4,912	27,144	19,628	12,816	3,504	15,629	7,523	3,888	8,257	37,872	1,193
(pupa)	Simulidae				1,876	264	1,764	2,364	828	213	2,837	131	1,260	871	5,364	-
(larva)	Tipulidae	*Antocha*	3	c	120	53	1,788	1,032	756	461	19	-	252	219	936	-
(larva)	Tipulidae				672	-	-	-	-	-	-	-	-	-	-	-
(pupa)	Tipulidae				-	96	96	-	-	69	-	-	-	-	-	-
(larva)	other				-	-	-	-	-	56	-	-	-	-	-	-
(adult)	other				316	403	300	268	648	1,128	277	224	504	361	720	357
(pupa)	other				-	-	-	32	-	-	-	-	-	-	-	-

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye, Steep, and Robinson Main, and Hatchery Riffle page 2)

Taxonomic Group			TV	FFG	Eye Main (RM 60.1)			Steep Main (RM 61.0)			Robinson Main (RM 61.9)			Hatchery Riffle (RM 66.6)		
					Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Hemiptera																
	Corixdae				-	-	492	-	36	187	-	21	216	-	-	388
	Macroveliidae				-	-	96	-	-	-	-	-	-	-	-	-
	Notonectidae				-	32	-	-	-	-	-	-	-	-	-	-
Order Lepidoptera																
(larva)	Pyralidae	*Petrophila*	5	g	156	192	-	64	180	-	-	108	-	-	-	-
(pupa)	Pyralidae				-	-	-	-	-	-	-	-	19	-	-	-
Order Odonata																
(naiad)	Coenagrionidae				-	-	-	-	-	19	-	-	72	-	-	-
Order Ephemeroptera																
(nymph)	Baetidae	*Acentrella*	4	c	164	11,696	144	36	13,824	4,563	35	7,168	2,556	113	648	4,479
(nymph)	Baetidae	*Baetis*	5	c	11,476	6,205	5,340	21,672	14,976	11,819	9,813	3,127	19,548	3,524	13,320	5,304
(nymph)	Ephemerillidae	*Serratella*	2	c	-	1,061	588	36	972	2,411	-	121	1,224	-	216	351
(nymph)	Leptoyphidae	*Tricorythodes*	5	c	600	1,072	72	176	144	2,168	21	-	432	195	216	572
(adult)	other				-	-	-	-	36	592	-	-	108	39	-	239
Order Plecoptera																
(nymph)	Periodidae	*Isoperia*	2	p	-	-	36	100	36	-	-	33	-	-	-	-
Order Trichoptera																
(larva)	Brachycentridae	*Amiocentrus*	3	c	-	-	-	-	-	69	-	-	-	-	-	-
(larva)	Glossosomatidae	*Glossosoma*	0	g	904	171	336	180	324	144	1,400	144	252	609	108	307
(larva)	Glossosomatidae	*Protoptila*	1	g	-	21	-	-	-	-	-	-	-	-	-	-
(pupa)	Glossosomatidae				76	347	24	36	684	69	16	304	72	-	36	51
(larva)	Hydropsychidae	*Hydropsyche*	4	f	2,172	1,779	2,292	10,084	3,816	18,232	149	191	14,040	308	540	6,432
(larva)	Hydropsychidae	*Cheumatopsych*	5	f	56	-	-	104	-	-	-	-	-	-	-	-
(pupa)	Hydropsychidae				-	509	312	-	252	56	-	-	180	-	-	51
(larva)	Hydroptilidae	*Oxyethria*	3	c	-	-	48	-	-	-	-	-	-	9	72	-
(larva)	Hydroptilidae	*Hydroptila sp.*	6	g	-	-	-	-	-	37	-	-	108	-	-	16
(larva)	Hydroptilidae				-	-	-	-	-	-	-	-	-	-	-	31
(pupa)	Hydroptilidae				-	32	-	-	-	88	-	-	144	20	-	-
(larva)	Lepidostomatidae	*Lepidostoma*	1	s	-	-	-	-	-	-	-	-	-	-	36	-
(larva)	Polycentropodidae				-	-	-	-	-	-	-	-	-	-	72	-
(larva)	Psychomylidae	*Psychomyia*	2	g	-	-	-	-	-	-	-	-	36	-	-	-
(larva)	Psychomylidae	*Tinodes sp.*	2	g	-	-	-	-	-	56	-	-	-	-	-	-
(pupa)	Psychomylidae				-	-	-	-	-	19	-	-	-	-	-	-
(larva)	Psychomylidae	*Rhyacophila sp.*	0	p	-	-	-	-	-	-	-	-	-	-	72	-
(adult)	Other				-	-	64	-	-	-	-	-	-	-	-	-
Order Amphipoda																
	Other				-	32	-	36	-	37	-	-	36	95	-	48
Order Aranea																
	Other				-	-	48	-	-	-	-	-	36	-	72	-
		Total Organisms			51,308	64,339	74,776	61,296	90,165	52,950	39,121	53,815	51,247	42,284	108,648	26,188

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye, Steep, and Robinson Main, and Hatchery Riffle page 3)

	Eye Main (RM 60.1)			Steep Main (RM 61.0)			Robinson Main (RM 61.9)			Hatchery Riffle (RM 66.6)		
	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Cumulative Taxa	20	26	35	23	27	31	15	17	29	21	24	25
EPT Taxa	7	10	11	9	10	14	6	7	12	8	11	11
Ephemeroptera Taxa	3	4	4	4	5	5	3	3	5	4	4	5
Plecoptera Taxa	0	0	1	1	1	0	0	1	0	0	0	0
Trichoptera Taxa	4	6	6	4	4	9	3	3	7	4	7	6
EPT Index	30	36	12	53	39	76	29	21	76	11	14	68
Sensitive EPT Index	2	2	1	1	1	5	4	1	3	1	0	3
Shannon Diversity	1.8	1.9	1.9	1.6	2.0	2.1	1.6	1.6	1.9	1.7	1.7	2.2
Tolerance Value	4.5	4.2	4.1	4.6	4.3	4.2	4.4	4.2	4.4	4.2	4.7	4.2
Percent Intolerant Organisms	6	6	9	1	4	7	12	3	4	12	3	4
Percent Tolerant Organisms	0	0	0	0	0	0	0	0	0	0	0	0
Percent Hydropsychidae	4	4	3	17	5	35	0	0	28	1	0	25
Percent Baetidae	23	28	7	35	32	31	25	19	43	9	13	37
Percent Dominant Taxon	32	40	36	35	23	34	40	44	38	45	35	25
Percent Collectors	79	90	74	69	87	54	86	96	62	82	95	61
Percent Filterers	14	8	21	30	11	46	1	2	36	6	3	37
Percent Grazers	7	2	3	1	2	1	12	2	1	12	1	2
Percent Predators	0	0	0	0	0	0	0	0	0	0	0	0
Percent Shredders	0	0	2	0	0	0	0	0	0	0	0	0

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye Side, Steep Side, Robinson Side, and Hatchery Ditch page 1)

Taxonomic Group					Eye Side (RM 60.1)			Steep Side (RM 61.0)			Robinson Side (RM 61.9)			Hatchery Ditch (RM 66.6)		
			TV	FFG	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Acari																
	Anasitsilidae				-	-	-	-	-	-	-	-	36	-	-	-
	Arreneuridae				-	-	-	-	-	24	-	-	-	-	-	-
	Hygrobatidae				-	-	-	-	72	64	-	-	105	-	-	144
	Lebertidae				88	272	371	-	1,147	488	48	468	589	14	41	1,936
	Oribatid				756	11,810	-	4,356	61,091	5,720	1,115	48,816	1,051	-	-	76,541
	Sperchontidae				64	491	197	36	637	376	108	756	287	3	99	645
	Torrenticolidae				-	20	-	36	421	368	-	36	36	-	-	-
(juvenile)	Unknown				-	36	57	-	-	40	-	-	48	-	-	72
	Unknown				-	-	-	-	-	-	-	-	-	-	41	71
Order Collembola																
	Hypogastruidae				-	20	-	24	-	-	-	-	-	8	-	-
Order Coleoptera																
(larva)	Unknown				-	36	40	-	-	-	-	-	-	-	-	-
(adult)	Unknown				-	-	56	-	-	-	11	-	45	25	24	-
(adult)	Curculionidae				-	-	-	-	72	-	-	-	-	-	-	-
(adult)	Dytiscidae				-	-	-	-	-	-	-	72	-	-	-	-
(adult)	Dytiscidae	*Liodessus*	5	p	-	-	-	-	-	-	-	36	-	-	-	-
(adult)	Dytiscidae	*Sanfilipodytes*	5	p	-	-	-	-	-	-	-	-	-	3	-	-
(larva)	Elmidae	*Optioservus*	4	g	40	36	-	-	-	-	-	-	-	-	-	-
(larva)	Elmidae	*Ordobrevia*	4	g	-	-	-	-	72	-	-	-	-	-	-	-
(larva)	Elmidae				-	-	-	-	-	-	-	-	24	-	-	-
(larva)	Hydrophilidae				-	-	-	-	-	-	-	-	-	3	-	-
(larva)	Staphylinidae				-	-	-	-	-	-	-	-	-	8	18	-
Order Diptera																
(larva)	Ceratopogonidae				-	-	-	-	-	-	-	216	-	-	-	-
(pupa)	Ceratopogonidae				-	-	-	-	-	-	-	-	45	-	-	72
(larva)	Chironomidae				1,140	10,691	11,960	4,908	27,139	872	1,566	27,612	577	2,999	11,960	10,151
(pupa)	Chironomidae				136	405	431	228	421	-	179	2,196	-	815	2,256	500
(larva)	Empididae	*Chelifera*	6	p	-	-	200	-	-	-	-	-	-	-	-	-
(larva)	Empididae				-	20	83	24	-	40	-	-	-	59	18	-
(pupa)	Empididae				-	-	-	-	-	-	-	-	-	-	24	-
(larva)	Ephydridae				-	20	-	-	-	-	-	-	-	-	-	-
(larva)	Psychodidae	*Pericoma*			-	-	-	-	-	-	-	-	-	-	18	-
(larva)	Simulidae				10,856	7,353	10,356	17,904	22,555	3,880	2,582	7,524	2,265	1,506	5,337	789
(pupa)	Simulidae				1,904	386	125	1,776	1,867	768	286	828	153	76	1,242	285

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye Side, Steep Side, Robinson Side, and Hatchery Ditch page 2)

Taxonomic Group			TV	FFG	Eye Side (RM 60.1)			Steep Side (RM 61.0)			Robinson Side (RM 61.9)			Hatchery Ditch (RM 66.6)		
					Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
(larva)	Tipulidae	*Antocha*	3	c	508	131	116	1,260	573	208	252	72	292	257	59	-
(larva)	Tipulidae	*Tipula*	6	p	-	-	40	-	-	-	-	-	-	-	-	-
(pupa)	Tipulidae				-	-	-	-	72	-	-	72	24	-	-	72
(larva)	other				-	-	-	-	-	-	-	-	-	6	-	-
(adult)	other				12	131	169	276	352	-	341	2,016	588	433	483	143
(pupa)	other				-	-	-	-	-	-	39	-	-	-	-	-
Order Hemiptera																
	Corixdae				-	144	-	-	-	16	-	144	632	-	-	143
	Macroveliidae				-	-	-	-	-	-	-	-	-	-	63	-
	Veliidae				-	-	-	-	-	-	-	-	60	-	-	-
Order Lepidoptera																
(larva)	Pyralidae	*Petrophila*	5	g	84	36	-	72	-	-	45	-	-	-	-	-
Order Ephemeroptera																
(nymph)	Baetidae	*Acentrella*	4	c	136	12,215	227	276	21,587	1,336	99	10,188	4,216	6	176	1,645
(nymph)	Baetidae	*Baetis*	5	c	12,432	9,949	11,839	28,224	16,851	18,544	12,151	5,328	13,192	526	4,348	37,645
(adult)	Baetidae				-	36	-	-	-	-	-	-	-	-	-	-
(nymph)	Ephemerillidae	*Serratella*	2	c	-	2,479	-	-	2,869	1,608	-	72	2,125	-	24	573
(nymph)	Leptoyphidae	*Tricorythodes*	5	c	1,616	804	-	336	-	3,072	84	648	2,284	-	-	17,047
(adult)	other				-	-	-	72	-	-	13	-	91	-	-	-
Order Plecoptera																
(nymph)	Periodidae	*Isoperia*	2	p	100	-	-	156	72	-	23	-	-	-	-	-
Order Trichoptera																
(larva)	Brachycentridae	*Amiocentrus*	3	c	-	-	-	-	-	-	-	-	-	-	-	72
(larva)	Glossosomatida	*Apegatus*	0	SC	-	-	41	-	-	-	-	-	-	-	-	-
(larva)	Glossosomatida	*Glossosoma*	0	g	1,432	975	7,268	264	-	664	2,345	180	348	226	617	-
(pupa)	Glossosomatidae				288	563	88	96	72	-	184	1,008	84	16	137	-
(larva)	Hydropsychidae	*Hydropsyche*	4	f	5,228	2,368	65	26,460	2,728	15,584	613	288	7,097	11	-	6,501
(larva)	Hydropsychidae	*Cheumatopsyche*	5	f	-	36	-	72	-	-	-	-	-	-	-	-
(larva)	Hydropsychidae				-	20	-	-	-	-	-	-	-	-	-	-
(pupa)	Hydropsychidae				-	252	-	24	360	192	-	36	72	-	-	72
(larva)	Hydroptilidae	*Oxyethria*	3	c	-	-	16	-	-	-	-	72	-	3	-	141
(larva)	Hydroptilidae	*Hydroptila sp.*	6	g	24	236	-	-	72	-	-	72	45	-	-	216
(larva)	Hydroptilidae				-	-	32	-	-	48	-	-	-	-	-	-
(pupa)	Hydroptilidae				-	-	-	-	-	-	-	-	45	-	-	143
(larva)	Lepidostomatida	*Lepidostoma*	1	s	-	-	708	-	-	-	-	-	-	17	24	-
Order Amphipoda																
	Other				12	20	-	-	-	16	23	-	36	-	-	720
Order Aranea																
	Other				-	-	80	-	-	16	36	72	-	-	-	-
Order Branchiopoda																
	Other				-	-	-	-	-	16	-	-	-	-	-	-
		Total Organisms			36,856	61,991	44,565	86,880	161,102	53,960	22,143	108,828	36,492	7,020	27,009	156,339

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye Side, Steep Side, Robinson Side, and Hatchery Ditch page 3)

	Eye Side (RM 60.1)			Steep Side (RM 61.0)			Robinson Side (RM 61.9)			Hatchery Ditch (RM 66.6)		
	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Cumulative Taxa	20	31	24	22	22	24	22	26	30	22	21	25
EPT Taxa	8	12	9	10	8	8	8	10	11	7	6	10
Ephemeroptera Taxa	3	5	2	4	3	4	4	4	5	2	3	4
Plecoptera Taxa	1	0	0	1	1	0	1	0	0	0	0	0
Trichoptera Taxa	4	7	7	5	4	4	3	6	6	5	3	6
EPT Index	58	48	46	64	28	76	70	16	81	11	20	41
Sensitive EPT Index	4	6	18	0	2	4	11	0	7	4	2	1
Shannon Diversity	1.8	2.2	1.7	1.6	1.8	1.9	1.6	1.7	2.1	1.7	1.6	1.5
Tolerance Value	4.4	4.1	3.1	4.5	4.2	4.4	4.2	4.3	4.3	3.3	4.3	4.8
Percent Intolerant Organisms	7	12	39	1	7	6	15	1	8	23	13	1
Percent Tolerant Organisms	0	0	0	0	0	0	0	0	0	0	0	0
Percent Hydropsychidae	14	4	0	31	2	29	3	0	20	0	0	4
Percent Baetidae	34	36	27	33	24	37	55	14	48	8	17	25
Percent Dominant Taxon	34	20	27	32	38	34	55	45	36	43	44	49
Percent Collectors	68	87	59	53	93	60	81	97	75	76	88	90
Percent Filterers	24	8	0	46	6	38	4	2	24	1	0	10
Percent Grazers	7	4	35	1	0	2	15	1	1	22	12	0
Percent Predators	0	0	3	0	0	0	0	0	0	2	0	0
Percent Shredders	0	0	1	0	0	0	0	0	0	0	0	0

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Shallow, MacFarland, Hour, Vance, page 2)

Taxonomic Group			TV	FFG	Shallow (RM 47.2)			MacFarland (RM 53.5)			Hour (RM 55.5)			Vance (RM 58.5)		
					Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Acari																
	Anasitsilidae				-	-	-	-	36	-	-	-	-	-	-	-
	Hygrobatidae				-	216	424	-	36	88	48	47	-	-	-	240
	Lebertidae				12	-	288	-	147	104	-	191	32	20	144	1,196
	Oribatid				5	828	264	76	1,381	40	416	6,300	424	1,536	5,760	1,268
	Sperchontidae				5	168	336	-	72	48	56	564	-	56	216	268
	Torrenticolidae				-	36	128	-	144	80	-	424	128	-	36	560
	juvenile				5	-	48	32	72	-	-	-	-	-	-	-
	unknown				-	-	-	-	36	-	-	-	-	-	36	-
Order Collembola																
	Hypogastruidae				17	72	-	-	36	-	16	93	-	-	-	-
Order Coleoptera																
(adult)	Curculionidae				-	-	-	40	24	-	-	-	-	-	-	-
	Dytiscidae	*Liodessus*	5	p	-	36	-	-	-	-	-	-	-	-	-	-
(larva)	Elmidae	*Ordobrevia*	4	g	-	-	-	-	-	48	-	-	-	-	36	-
(adult)	Elmidae				-	-	-	-	-	56	-	-	-	-	-	-
(adult)	Staphylinidae				-	-	-	-	24	48	-	-	-	-	111	-
Order Diptera																
(larva)	Ceratopogonidae				-	-	-	-	-	-	-	-	24	-	-	-
(pupa)	Ceratopogonidae				-	-	-	-	-	48	-	-	-	-	-	-
(larva)	Chironomidae				1,772	18,504	7,704	13,356	9,396	1,464	9,436	23,575	1,128	17,924	14,773	8,728
(pupa)	Chironomidae				104	1,008	1,344	1,176	444	216	448	1,488	176	1,472	1,057	572
(larva)	Empididae				12	-	-	-	-	-	-	-	-	-	-	-
(larva)	Simulidae				3,501	756	408	7,068	5,472	264	2,252	341	48	5,792	293	612
(pupa)	Simulidae				1,093	72	40	2,000	588	-	756	47	-	948	111	-
(larva)	Tipulidae	*Antocha*	3	c	12	72	-	152	96	40	-	-	40	108	443	56
(pupa)	Tipulidae				-	-	-	-	-	56	-	-	-	-	-	-
	Other Dipterans				255	396	40	436	660	1,400	292	973	32	784	2,793	168
Order Ephemeroptera																
(nymph)	Baetidae	*Acentrella*	4	c	187	7,416	8,176	52	10,992	25,600	140	7,980	10,344	292	4,144	18,680
(nymph)	Baetidae	*Baetis*	5	c	6,747	1,800	408	15,472	4,428	2,888	4,344	2,427	6,816	7,480	3,335	11,104
(nymph)	Ephemerillidae	*Serratella*	2	c	-	1,584	5,440	16	23,400	10,944	-	8,743	10,328	-	25,135	5,928
(nymph)	Heptogeniidae				24	-	-	-	-	-	-	-	-	-	-	-
(nymph)	Leptohyphidae	*Asioplax*	4	CG	48	-	-	-	-	-	-	-	-	-	-	-
(nymph)	Leptohyphidae	*Tricorythodes*	5	c	188	108	1,200	400	-	1,056	388	93	3,696	68	72	2,316

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Shallow, MacFarland, Hour, Vance, page 2)

Taxonomic Group			TV	FFG	Shallow (RM 47.2)			MacFarland (RM 53.5)			Hour (RM 55.5)			Vance (RM 58.5)		
					Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
(adult)	Other Ephemeroptera				-	72	-	360	-	40	-	1,811	-	-	833	300
Other Plecoptera																
(nymph)	Perlodidae	*Isoperla*	2	p	711	-	-	728	-	-	20	-	-	-	36	-
Order Trichoptera																
(larva)	Glossosomatidae	*Glossosoma*	0	g	381	-	40	-	396	-	196	269	32	236	-	184
(larva)	Glossosomatidae	*Protoptila*	1	g	-	-	-	-	72	-	-	-	-	-	-	-
(pupa)	Glossosomatidae				97	36	-	-	120	48	-	72	-	124	36	84
(larva)	Hydropsychidae	*Hytropsyche*	4	f	8,444	5,976	7,552	25,252	5,676	13,864	12,812	13,395	16,282	22,184	10,132	35,120
(larva)	Hydropsychidae	*Cheumatopsych*	5	f	29	432	112	696	60	832	272	521	528	588	291	936
(pupa)	Hydropsychidae				-	1,044	376	-	468	136	-	615	464	36	725	572
(larva)	Hydroptilidae	*Oxyethira*	3	c	-	-	-	-	-	-	-	-	-	-	-	72
(larva)	Hydroptilidae	*Hydroptila sp.*	6	g	-	36	200	164	-	88	336	223	360	48	149	1,376
(larva)	Hydroptilidae				-	-	-	-	-	-	-	93	-	-	-	-
(pupa)	Hydroptilidae				-	72	160	-	96	96	-	248	88	-	-	716
(larva)	Leptoceridae	*Ceracleas*	4	CG	-	-	-	-	36	-	-	-	-	-	-	-
Order Hempitera																
	Corixidae				-	36	24	-	24	-	20	108	48	-	-	144
	Hebridae				-	-	-	-	-	-	-	93	-	-	-	-
Order Lepidoptera																
(larva)	Pyralidae	*Petrophila*	5	g	183	-	-	-	36	-	36	119	-	92	75	-
(larva)	Pyralidae				-	-	16	-	-	928	-	-	240	-	-	832
(pupa)	Pyralidae				-	-	-	-	24	48	-	-	-	-	-	-
		Total Organisms			23,832	40,776	34,728	67,476	64,492	60,568	32,284	70,853	51,258	59,788	70,772	92,032

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Shallow, MacFarland, Hour, Vance, page 3)

	Shallow (RM 47.2)			MacFarland (RM 53.5)			Hour (RM 55.5)			Vance (RM 58.5)		
	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Cumulative Taxa	23	24	23	18	31	28	19	27	21	19	25	25
EPT Taxa	10	11	10	9	11	11	8	13	10	9	11	13
Ephemeroptera Taxa	5	5	4	5	3	5	3	5	4	3	5	5
Plecoptera Taxa	1	0	0	1	0	0	1	0	0	0	1	0
Trichoptera Taxa	4	6	6	3	8	6	4	8	6	6	5	8
EPT Index	71	46	68	64	71	92	57	52	95	52	63	84
Sensitive EPT Index	5	4	16	1	37	18	1	13	20	0	36	7
Shannon Diversity	1.8	1.8	2.0	1.7	2.0	1.7	1.7	2.1	1.8	1.7	2.0	2.0
Tolerance Value	4.2	4.0	3.6	4.4	3.0	3.7	4.3	3.6	3.8	4.2	2.9	4.1
Percent Intolerant Organisms	6	9	24	2	53	20	1	27	21	1	57	8
Percent Tolerant Organisms	0	0	0	0	0	0	0	0	0	0	0	0
Percent Hydropsychidae	36	18	23	38	10	24	41	21	34	38	16	40
Percent Baetidae	29	23	25	23	24	47	14	15	33	13	11	32
Percent Dominant Taxon	35	45	24	37	36	42	40	33	32	37	36	38
Percent Collectors	42	63	66	37	86	73	26	57	64	26	76	50
Percent Filterers	50	37	33	60	13	27	71	41	35	73	24	48
Percent Grazers	3	0	1	0	1	0	3	2	1	1	1	2
Percent Predators	0	0	0	0	0	0	0	0	0	0	0	0
Percent Shredders	4	0	0	2	0	0	0	0	0	0	0	0

APPENDIX B--PHYTOPLANKTON RAW DATA

Table B-1. List of plankton sampling stations by name and habitat area.

Station Name	Habitat Area
Lake Oroville North Fork	Area Upstream of Lake Oroville Inundation Zone
Lake Oroville Middle Fork	Area Upstream of Lake Oroville Inundation Zone
Lake Oroville South Fork	Area Upstream of Lake Oroville Inundation Zone
Lake Oroville Main Body	Lake Oroville Reservoir
Lake Oroville above Dam	Lake Oroville Reservoir
Thermalito Diversion Pool Upstream Fish Barrier Dam	Thermalito Diversion Pool
Thermalito Diversion Pool Upstream Powerplant	Thermalito Diversion Pool
Thermalito North Forebay	Thermalito Forebay
Thermalito South Forebay	Thermalito Forebay
Thermalito North Afterbay	Thermalito Afterbay
Thermalito South Afterbay	Thermalito Afterbay
Oroville Fishing Pond	Oroville Wildlife Area
Robinson Riffle Pond	Oroville Wildlife Area
Mile Long Pond	Oroville Wildlife Area

Source: (pers.comm., J. Boles, DWR 2003/2004)

Table B-2. Total count and relative proportion of phytoplankton organisms from five locations upstream of Oroville Dam.

Taxa Description	Area Upstream of Lake Oroville Inundation Zone			Lake Oroville Reservoir	
	Lake Oroville North Fork	Lake Oroville South Fork	Lake Oroville Middle Fork	Lake Oroville at Dam	Lake Oroville Main Body
Blue-greens	23	14	20	17	15
Cryptomonads	16	28	16	13	8
Diatoms	161	161	117	105	34
Dinoflagellates	8	4	2	2	4
Euglenoids	0	6	2	2	1
Flagellates	3	5	1	5	3
Greens	19	15	15	10	17
Yellow-browns	17	21	26	12	5
Yellow-greens	0	3	0	0	0
Grand Total	247	257	199	166	87

Table B-3. Total count and relative proportion of phytoplankton, by family, from four locations in the Thermalito Complex and two sites immediately downstream of Oroville Dam.

	Thermalito Diversion Pool		Thermalito Afterbay		Thermalito Forebay	
Taxa Description	Thermalito Diversion Pool Upstream Fish Barrier Dam	Thermalito Diversion Pool Upstream Power Plant	Thermalito North Afterbay	Thermalito South Afterbay	Thermalito North Forebay	Thermalito South Forebay
Blue-greens	5	4	21	19	23	16
Cryptomonads	9	0	18	31	11	12
Diatoms	46	4	222	261	205	196
Dinoflagellates	0	4	2	2	2	3
Euglenoids	0	1	1	0	0	0
Flagellates	4	0	8	4	2	4
Greens	5	20	34	35	25	27
Yellow-browns	2	1	9	14	11	15
Yellow-greens	0	0	0	0	0	0
Grand Total	71	34	315	366	279	273

Table B-4. Total count and relative proportion of phytoplankton, by family, from three locations in the Oroville Wildlife Area.

	Oroville Wildlife Area		
Taxa Description	Mile Long Pond	Oroville Fishing Pond	Robinson Riffle Pond
Blue-greens	39	35	4
Cryptomonads	4	63	9
Diatoms	55	21	7
Dinoflagellates	3	13	2
Euglenoids	0	12	1
Flagellates	1	3	0
Greens	44	152	13
Yellow-browns	1	4	0
Yellow-greens	0	0	0
Grand Total	147	303	36

APPENDIX C--ZOOPLANKTON RAW DATA

Table C-1. Zooplankton (number per liter) collected by DWR from Lake Oroville, Middle Fork Station.

		Date						
Taxonomic Group	Scientific Name	5/23/02	8/14/02	9/19/02	10/23/02	11/21/02	1/15/03	1/21/04
Cladocera	*Bosmina longirostris*	0.02	1.078	3.039	2.255	0.269	2.647	0.416
	Daphnia pulex	1.73						0.172
	Daphnia rosea	0.24	4.902	0.392	1.176	0.074	0.098	
	Daphnia galeata mondotae	0.08						
	Daphnia sp.							1.152
	Diaphansoma birgei		0.588	2.353	0.294			
	Leptodora kindti		0.196	0.098				
Copepoda	*Cyclops* sp.	0.16	0.980	2.941	1.471	1.103	5.098	1.152
	Leptodiaptomus tyrrelli	0.08	4.020	12.353	0.098	0.147	1.078	0.049
	Nauplii	1.98	6.569	9.902	1.569	1.397	9.608	1.912
Rotifers	*Asplanchna* sp.	0.45	1.863	0.784	2.892	0.417	3.334	
	Kellicottia longispina	0.90	0.196	0.098	0.049		0.784	0.319
	Keratella cochlearis	0.06	5.098	10.686	10.882	1.422	9.706	0.270
	Keratella quadrata							0.759
	Polyarthra sp.	0.41			2.402	1.618	8.039	
	Tichocerca sp. 1		7.745	0.686		1.446		
	Tichocerca sp. 2		0.980		0.294			

Table C-2. Zooplankton (number per liter) collected by DWR from Lake Oroville, South Fork Station.

		Dates			
Taxonomic Group	Scientific Name	5/24/02	9/19/02	10/23/02	11/21/02
Cladocera	*Bosmina longirostris*		4.510	5.000	0.817
	Daphnia pulex	8.088			
	Daphnia rosea	0.735	0.196		
	Daphnia galeata mondotae				
	Daphnia sp.			0.049	0.065
	Diaphansoma birgei		1.667	0.196	
	Leptodora kindti		0.098	0.098	
Copepoda	*Cyclops* sp.	4.019	1.176	2.157	1.242
	Leptodiaptomus tyrrelli	0.343	4.216	0.294	0.098
	Nauplii	9.657	16.373		
Rotifers	*Asplanchna* sp.	3.382	2.549	2.500	0.752
	Kellicottia longispina	0.294	0.049		
	Keratella cochlearis	0.098	13.431	25.882	2.745
	Lecane sp.		1.814	4.706	0.196
	Polyarthra sp.	0.392	2.059	25.254	6.503
	Tichocerca sp.		8.186		

Table C-3. Zooplankton (number per liter) collected by DWR from Lake Oroville, North Fork Station.

		Date
Taxonomic Group	Scientific Name	10/21/03
Cladocera	*Alona sp.*	
	Bosmina longirostris	2.304
	Daphnia pulex	1.029
	Diaphansoma birgei	0.049
Copepoda	*Cyclops* sp.	5.588
	Leptodiaptomus tyrrelli	0.343
	Nauplii	2.990
Rotifers	*Keratella cochlearis*	16.716
	Keratella quadrata	0.833

Table C-4. Zooplankton (number per liter) collected by DWR from Lake Oroville, Main Body of Reservoir Station.

		Date		
Taxonomic Group	Scientific Name	7/17/02	11/20/02	7/21/03
Cladocera	*Bosmina longirostris*	0.221	0.294	0.588
	Daphnia pulex			0.294
	Daphnia sp.	0.049	0.294	2.549
Copepoda	*Cyclops sp.*	0.172	2.059	8.334
	Leptodiaptomus tyrrelli	0.221	0.196	0.686
	Nauplii	0.515	3.922	9.216
Rotifers	*Asplancha* sp.	3.284	1.471	
	Kellicottia longispina	0.098	0.098	2.255
	Keratella cochlearis	0.784	10.490	2.451
	Keratella quadrata			4.706
	Polyarthra sp.	0.269	4.608	

Table C-5. Zooplankton (number per liter) collected by DWR from Lake Oroville, Near Dam Station.

		Date	
Taxonomic Group	Scientific Name	9/22/03	11/17/03
Cladocera	*Bosmina longirostris*	0.588	0.490
	Daphnia pulex	3.235	0.294
	Daphnia sp.	0.784	2.059
Copepoda	*Cyclops* sp.	23.334	2.941
	Leptodiaptomus tyrrelli	0.686	0.686
	Nauplii	12.647	11.176
Rotifers	*Kellicottia longispina*	1.569	1.863
	Keratella cochlearis	55.588	36.176
	Keratella quadrata	2.059	8.334

Table C-6. Zooplankton (number per liter) collected by DWR from Thermalito Afterbay, South Station.

		Date
Taxonomic Group	Scientific Name	5/23/02
Cladocera	Bosmina longirostris	0.490
	Daphnia pulex	1.471
	Daphnia sp.	4.509
Copepoda	*Cyclops* sp.	6.176
	Leptodiaptomus tyrrelli	0.392
	Nauplii	10.784
Rotifers	*Kellicottia longispina*	0.196
	Keratella cochlearis	0.784
	Keratella quadrata	0.490